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INTRODUCTION

The Alberta Office of Coal Research and Technology was established January 20, 1984, by Ministerial Order under the Department of Energy and Natural Resources Act.

Its purpose is to co-ordinate the Alberta government funding needed to identify, investigate and develop coal-related technologies considered to be commercially important during the next decade. These technologies are to:

- enhance the competitiveness of Alberta's coals in international markets;
- minimize the environmental impact of the production or use of coal in Alberta; and
- result in new uses for Alberta's coals.

Appointed to the Office are R. Douglas McDonald as Chairman, and Garnet T. Page and Michael A. Ward as Members. T. David Brown represents Energy, Mines and Resources Canada as an observer and participates in project reviews.

Initial funding of $20 million has been allocated from the Alberta/Canada Energy Resources Research Fund to provide financial support for research projects.

"A successful Alberta Coal Research Strategy depends on the wise collaboration of government, industry and the research community."

CHAIRMAN'S REPORT

The Alberta coal industry continues to face adverse conditions in international markets as the world-wide oversupply of coal continues to depress sales and prices. Alberta producers have achieved major improvements in operating efficiencies and productivity, but sometimes at the expense of future mine development. This means the health of the industry is being compromised and may become critical if the current situation continues.

An important result of these conditions is the increased awareness of industry for the role that new technology can, and must, play to enhance the competitiveness of Alberta coals world-wide. This has resulted in intensive discussions among the coal industry, the coal research community and governments regarding coal research and development (R&D) challenges, priorities and co-ordination. The Alberta Office of Coal Research and Technology remains committed to encouraging concerted action by Alberta's coal industry, the coal research community and governments to ensure the development and application of new technology in a timely and co-ordinated manner to enhance the competitiveness of Alberta coals in various provincial, national or international coal markets.

This commitment is complicated by the provincial government's budget deficit resulting from a major drop in international energy prices. The deficit has resulted in a severe reduction of R&D funding available through the Office, and the need for increasingly careful assessment of the Office's research funding priorities for 1987/88. Reflecting the current interest in promoting the use of western Canadian coals in Ontario, the Office's research priorities for 1987/88 will focus on: (1) new transportation initiatives, which can significantly affect the delivered cost of coal in Ontario; and (2) projects initiated in previous years.

The Alberta Office of Coal Research and Technology has reached a certain level of maturity during its third year of operation. It continues to work closely with the coal industry to identify technological opportunities considered to be important to coal producers and users. Forty-seven research projects were supported during the 1986/87 fiscal year. Research funding contributions by the Office totalled $5 478 800, whereas contributions by industry and other groups totalled $3 716 061, representing 40 per cent of total research expenditures.

A major initiative during 1986/87 was to contribute funding toward the development of the PYROSOL coal/heavy oil co-processing technology for production of transportation fuels. This technology can lead to a major increased demand for coal within Alberta as heavy oil and bitumen production continue to increase.

A second initiative undertaken with industry and the Alberta Research Council relates to coal gasification technology and the need to understand the behaviour of Alberta coals in different gasification systems. It is expected that future coal markets increasingly will reflect the interest of electricity-generating utilities in this technology. This initiative has resulted in the Office establishing a national Coal Gasification Technical Committee to encourage Canada-wide collaboration and co-operation in coal gasification R&D activities.

The ongoing industry/government coal combustion and utilization research program resulted in one project related to coal gasification technology, and a second related to development of combustion equipment that will allow the use of coal as an alternative for natural gas in heavy oil production.

Meanwhile, a new advance-retreat underground mining scheme, developed previously by the Coal Mining Research Company, was implemented at the Smoky River Coal Limited mine near Grande Cache and has led to significantly lower coal extraction costs.

The Office continues to collaborate with the Alberta Research Council and the Coal Mining Research Company to focus the research capabilities of these organizations on the needs of the coal industry. The Coal Research Grants Program was also restructured to achieve a better response to its primary objectives.

Several changes took place during the year which improved the Office's administrative procedures. Administrative support was provided by the staff of Alberta Department of Energy, Scientific and Engineering Services and Research Division, under the direction of Dr. P.F. Ziemkiewicz. Assistance was also provided by the Coal Research Technical Panel, the Interdepartmental Group for Coal Research and The Coal Association of Canada.

BACKGROUND

Alberta's coal industry provided an important energy source during the early

development of the province, and it continued to contribute significant economic activity until about 1950 when the coal market collapsed. In the mid-1960s, a resurgence occurred in the export market for metallurgical coal and in the provincial market for thermal coal. By 1974, annual production had risen to 9.5 million tonnes.

From 1975 to 1985, Alberta's raw coal production rose steadily, reaching 27.7 million tonnes, where it remained throughout 1986. Marketable coal, however, rose slightly from 24 million tonnes in 1985 to 24.5 million tonnes in 1986. This resulted from increased production of subbituminous coals and increased yields of cleaned bituminous coals.

In 1986, coal sales earned revenues of approximately $550 million for Alberta's coal producers. This income was derived from exports of bituminous coals, and combustion of subbituminous coals by Alberta utilities to produce almost 91 per cent of Alberta's electricity. Approximately 2 600 people were directly employed by Alberta's coal producers.

These statistics underline some of the benefits and the importance of Alberta's coal industry, but there are other advantages to having a healthy coal industry in the province. For example, coal mines provide a very high economic and social return on the land used. Also, the sale of coal to other countries improves Canada's trade balance, contributes to expansion of the provincial transportation network, and fosters growth in the provincial construction industry during periods of expansion. Other direct benefits include financial contributions to the three levels of government, and the purchase of goods and services within Alberta.

It is expected that Alberta's coal industry will continue to encourage the growth of secondary industries, provide a reliable and economic energy source for the recovery of the province's heavy oils and bitumen, and make other significant contributions to the province's economic base.

To optimize these benefits, however, coal exporting companies must first deal with concerns such as the current oversupply of coal world-wide. This competitive environment is worsened by the economic conditions in Japan, Canada's largest single coal export market, where demand for metallurgical coal, and the price that customers are willing to pay, have dropped sharply.

In the case of thermal coal exports, offshore markets are not developing significantly because of lower electricity demand and falling oil prices on the international market. Also, Ontario Hydro, the largest Canadian customer outside Alberta for thermal coal from the province, is expected to reduce its coal requirements until at least 1992.

Today's difficult market conditions make it essential that Alberta coal producers use the most efficient and economical technologies available in coal exploration, production, preparation, upgrading, transportation and marketing. Increasingly, overseas customers are demanding coal and coal products that exhibit specific qualities and behaviour. This means coal producers must know more about the combustion characteristics of their products and be involved in the development of new technologies such as agglomeration, coal-water fuels and other upgrading processes that will produce coal products tailored to market requirements.

The Alberta coal industry's response to these difficulties and challenges is expressed in the Alberta Coal Research Strategy, published in November 1983, which was the result of extensive discussions among individual companies and the provincial government. Later, the Office of Coal Research and Technology was established and subsequent industry proposals have resulted in jointly funded research and development projects. Additional support, designed to foster fundamental research beneficial to the coal industry, is provided by the Office of Coal Research and Technology's Coal Research Grants Program.

Another important function provided by the Alberta Office of Coal Research and Technology is the co-ordination of coal research and development activities within Alberta, as well as between Alberta, national and international agencies. This has led to a better integration among the various coal research groups in Alberta. Also, it has resulted in a stronger focus on the needs of industry, and has produced international contacts and greater international co-operation.

The Office has directly influenced research and development activities within Alberta by funding projects jointly with individual coal-producing companies or groups of companies, and with other government agencies, universities, private research organizations, consultants, utilities, equipment suppliers and agencies in other countries.

The Office is influencing coal research and development elsewhere by participating on various national and international committees, such as the International Energy Agency's Working Party for Fossil Fuels and the Canada/Japan Coal Conversion Research and Development Committee.

COAL RESEARCH STRATEGY

RESEARCH RATIONALE

Consistent with the views of the Government of Alberta, the Alberta Office of Coal Research and Technology believes the private sector should take the lead in identifying and managing appropriate research and development programs, as well as implementing and commercializing the results. The role of the Office, and other government agencies such as the Alberta Research Council, along with universities and research organizations such as the Coal Mining Research Company, is to support the private sector to the extent necessary to achieve the desired technical results in the most efficient manner.

While recognizing the need for longer-term research and development, as well as basic research to facilitate a better understanding of coal properties and uses, the critical time for commercial expansion and economic development of the province's coal resources is the period from 1988 to 1998. During this time, growth in thermal coal use throughout the world is probable, but increased competition can be expected from other coal-exporting countries. To what extent this expansion of thermal coal use can be realized, however, will depend on the prices of other energy supplies,

particularly natural gas, oil and nuclear power, and the relative social and environmental acceptance of coal versus other fuels.

New initiatives are required now, to ensure that Alberta coal achieves a maximum economic impact within the next 15 years. Toward this end, in 1984 the Alberta Office of Coal Research and Technology identified initial funding through the Alberta/Canada Energy Resources Research Fund of approximately $20 million in support of agreed research, development or demonstration projects. It was anticipated that similar funding would be forthcoming from the private sector. A portion of the funding is being used for longer-term or fundamental research directed toward innovative technologies related to production and use of Alberta coals.

Alberta must collaborate closely with research groups elsewhere to ensure that maximum benefit is derived from the total international coal research and development effort, and to define its intermediate- and long-term plans within this context.

In pursuing its objectives, the Alberta Office of Coal Research and Technology works closely with The Coal Association of Canada to establish research and development priorities. It also collaborates with the Consulting Engineers of Alberta to develop and maintain a list of engineering skills available for coal research, development and project work in the province. In addition, the Office maintains world-wide contacts with researchers engaged in coal-related studies.

ADMINISTRATIVE FRAMEWORK

The Alberta Office of Coal Research and Technology does not have in-house facilities to carry out research projects. Rather, its primary role is to provide funding for approved coal research projects. Therefore, procedures have been established to ensure sound project management by the researchers and financial control of approved projects. Specific agreements are signed for each project, which define the terms and conditions under which the project will be conducted and funded. These agreements also define the respective rights of new project technology ownership and use.

Each proposal receives thorough consideration and a prompt response. Proposals considered to fall within the Alberta Coal Research Strategic Plan are discussed in detail with the applicant, and are often referred in confidence to one or more experts for detailed technical review.

The president of The Coal Association of Canada also reviews a summary of each proposal on a confidential basis and provides comments on implications for the coal industry.

An Alberta government interdepartmental group has been established to review and comment on the implications of the proposed research. This group includes representatives from the Energy Resources Conservation Board and the departments of Forestry, Lands and Wildlife, Economic Development and Trade, Environment, and Community and Occupational Health.

Approval of research proposals by the Members of the Alberta Office of Coal Research and Technology is based on the results of these reviews, relative funding contributions and the likelihood that the proposed research will contribute to achieving the goals of the Alberta Coal Research Strategic Plan. Those projects funded within the Alberta/Canada Energy Resources Research Fund (A/CERRF) are subsequently submitted to the A/CERRF Committee for approval.

Applications received within the scope of the Alberta Coal Research Grants Program are reviewed by the Alberta Office of Coal Research and Technology to ensure they are consistent with the objectives of this program. Applications are then considered in detail by the Coal Technical Review Panel, which makes recommendations to the Office regarding the merits, associated funding and the extent to which the application should be supported by the Office.

RESEARCH PROGRAM

INTRODUCTION

The research program supported by the Alberta Office of Coal Research and Technology is guided by the Alberta Coal Research Strategy. Its objectives are to ensure that the coal-related technologies necessary to permit realization of the full economic potential of Alberta's coal deposits are available in a timely manner, through a co-operative effort involving the private sector, the research community and government.

Technologies that are likely to be commercially important from 1988 to 1998 will be identified, investigated and developed to:

- enhance the competitiveness of Alberta coals in international markets;
- minimize the environmental impact of the production or use of coal in Alberta; and
- result in new uses for Alberta coals.

Based on discussions with industry and the research community, the following research and development program areas have been identified as opportunities for further investigation. They are:

- Exploration
- Mining
- Preparation and Upgrading
- Combustion
- Liquefaction
- Gasification
- Transportation
- Environment
- Markets

In each of these research areas, all projects must consider workers' health and safety during both the research stage and subsequent commercial-scale applications.

RESEARCH PRIORITIES

Since the Alberta Coal Research Strategy was prepared in 1983, several important events have occurred which could significantly affect Alberta coal producers, particularly those depending on export sales.

In Japan, a drop in demand for steel and changes in technology have allowed steel producers to use lower quality, "soft" and "weak" coking coals. This is forcing Alberta producers of high-quality coking coals to lower their prices. This trend is expected to continue and will result in new specifications for coking coal quality and performance.

Ontario Hydro is considering the use of more low-sulphur western Canadian coals to help meet provincial acid gas emission guidelines and establish a reliable domestic coal supply. This has resulted in a commitment by both industry and government to reduce the delivered cost of western Canadian coal in Ontario.

World-wide, the development of new coal utilization technologies is generating demand for certain types of internationally traded thermal coals. Suppliers are now aware that they should be providing thermal coals tailored to satisfy the requirements of these new systems. Their success in these markets will depend on them having a better understanding of the performance charactertistics of their products under different operating conditions.

These changes have been influential in bringing about some modifications to the research priorities of the Alberta Office of Coal Research and Technology. Currently, those priorities are:

- to enhance opportunities for sales of Alberta coals in Ontario by ensuring the availability of competitively priced, high-quality products. This includes assessing the potential of alternative technologies and transportation systems, as well as pursuing prospective market opportunities;
- to enhance opportunities for sales of Alberta coals in export markets by ensuring that the performance characteristics of these coals in a variety of applications are fully understood, and that improved products are developed to meet the needs of emerging technologies. This includes encouraging co-operative, knowledge-sharing programs among Alberta coal producers, potential users and the developers of new technologies; and
- to expand opportunities to use coal in Alberta, particularly for producing and upgrading heavy oil and oil sands. Currently, the emphasis is on steam raising for enhanced recovery of heavy oil, and on co-processing of heavy oil and coal to produce refinery feedstocks for transportation fuels.

Although coal underlies about 46 per cent of Alberta, much of it is either buried too deeply for economically viable mining, is discontinuous, or is unsuitable for a particular market. The coal exploration challenge thus becomes one of determining the quantity and quality of mineable coal, the geometry of the rock formations of interest, the properties of the overburden material, and estimating mining costs for planning a mine.

The traditional prospecting methods for coal exploration include inspection of outcrop and drilling programs to acquire subsurface rock formation geometry and data on coal quality, hydrogeology and geophysics. The results are plotted on maps by hand or by computer-assisted drafting techniques, and are then interpreted by a geologist or engineer. Research and development efforts by Alberta's industry seek to make greater use of surface and downhole geophysical data, integrated with computer-assisted design techniques, to reduce exploration costs and increase both the amount and quality of information available to mine planners. Research into new and better interpretation techniques for geological and engineering data is also in progress.

Highlights of five coal exploration projects which received funding contributions from the Alberta Office of Coal Research and Technology follow.

SURFACE GEOPHYSICAL COAL EXPLORATION

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS

Researchers are investigating the potential of various geophysical exploration techniques to define details about the coal environment which are important for mine development in the plains area. Features of interest include formation subcrops, faults, the water table and glacial till.

During the third and final year of the surface geophysical project, the exploration methods developed earlier were refined by a detailed study of subsurface materials and coal at a test location on the Genesee mine site, which is operated by Fording Coal Limited for Edmonton Power. Field work consisted of 2 400 metres of reflection seismic, refraction seismic, electromagnetic and resistivity survey lines. In addition, four coreholes, eight rotary and four crosshole survey boreholes were drilled by the Alberta Research Council. Experiments were also conducted with an innovative seismic energy source provided by the United States Bureau of Mines.

The research demonstrated that an integrated program of surface geophysics and borehole geology produces a more reliable picture of subsurface geological and geotechnical conditions than either method used alone. In particular, this allows coal subcrop and bedrock channel geometry to be defined more accurately.

DOWNHOLE GEOPHYSICS

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS

The coal mining industry in Alberta has identified the need for additional information about subsurface geological materials and conditions for mine planning and design. However, the high cost of conventional drilling operations limits the number of boreholes that can be drilled at any particular site, and the cost of laboratory methods for determining rock properties limits the amount of information that can be obtained from them. Although borehole geophysical logging has been done for many years, it is generally believed that more information should be available from the logged data than has been derived thus far.

Consequently, existing methods are being evaluated and new techniques are being developed to use borehole geophysical data in determining the geotechnical and hydrogeological characteristics of subsurface materials.

The first phase of the project, which was a state-of-the-art review, generally confirmed the idea that more could be done with existing data, but also revealed additional applications for new logging tools and data-processing technology.

IN-SEAM COAL CHARACTERIZATION

COAL MINING RESEARCH COMPANY, DEVON

It is possible that borehole geophysical methods can be used to assess the quality and chemical composition of coal while it is still in the ground. If so, the information that might be made available would be of considerable value to mining companies in deciding which coal deposits to mine. Until now, limited information about coal quality has been available before mining because it is expensive to drill boreholes, excavate test pits and conduct laboratory analyses. However, the use of geophysics in conjunction with a conventional

The location of coal subcrops can be defined by measuring the resistance of the ground to direct electrical current.

Analysis of the Livingstone Thrust Plate (shown here) reveals the complex structural environment in which coal is found.

borehole program could provide significantly more and better quality data at lower cost. Consequently, the Coal Mining Research Company has begun to develop methods of interpreting existing data and evaluating new equipment designed to measure characteristics of unmined coal.

The technical literature was surveyed and reviewed to establish the state-of-the-art, and available equipment for borehole spectroscopy, geophysical logging, laboratory coal quality analysis, and modelling empirical coal quality by computer was determined.

The literature survey and review revealed that two approaches to the problem were available: (1) the use of empirical analysis to derive quality models from geophysical logs; and (2) a more deterministic modelling strategy based upon borehole spectroscopy techniques. It is believed the physical characteristics of the coal (or proximate analysis) can be satisfactorily determined by the first approach, while coal chemistry and heating value analysis (or ultimate analysis) should be possible from the second.

The results from a questionnaire sent to coal-producing companies suggest that few digital data bases of geophysical logs, as well as proximate and ultimate analyses, are being maintained, or are available for correlation purposes. Consequently, it may be necessary to acquire some field data to satisfactorily establish empirical models. Some software is available already. These programs will be evaluated in the next fiscal year.

PUBLICATIONS:

Wilson, R.A. 1986. ***In-Seam Coal Characterization, Phase I.*** *CMRC Report MO 8602.*

Wilson, R.A. and R.G. Chopiuk. 1987. ***In-Seam Coal Characterization, Phase 2.*** *CMRC Report MO 8602.2*

STRUCTURAL GEOMETRY OF IMBRICATED THRUST SHEETS

UNIVERSITY OF CALGARY, (D.A. SPRATT), CALGARY

This project, funded through the Coal Research Grants Program, is examining the three-dimensional geometries of three well-exposed areas of imbricate thrusting in Jurassic-Cretaceous strata of the Highwood and Oldman basins in southwestern Alberta. It is believed this will enable structures that are common to all areas, as well as structures that have developed only in particular settings, to be recognized and delineated. The resulting classification of three-dimensional Jurassic-Cretaceous structures, recognized by their outcrop patterns, should be applicable throughout the fold and thrust belt. This could lead to economic savings during the early stages of coal exploration in this and other thrust belts by providing the ability to identify shallowly buried reserves from an examination of the surface geometry of the overlying strata.

The Livingstone, Coleman and McConnel thrust sheets were mapped in detail during the 1985 and 1986 field seasons. Available oil and gas exploration well data and seismic information were used to complement field observations.

It was found that the three-dimensional configurations of the coal-bearing strata vary over short distances. Field data from this study have shed new light on the development, delineation and prediction of similar structures in the eastern foothills belt of southern Alberta.

An anomalous fault block, containing coal seams that apparently have been protected from some of the forces contributing to the coalification process, has been discovered in the Highwood area and will be the focus of further work after this project is completed.

SEISMIC MODELLING OF SHALLOW COALFIELDS

UNIVERSITY OF CALGARY, (D.C. LAWTON), CALGARY

In this project, funded by the Coal Research Grants Program, the effect of variations in the thickness, number and continuity of coal seams on the character of seismic reflection waveforms is being assessed by seismic modelling. This involves numerical techniques as well as the artificial production of seismic responses in laboratory-scale physical models. To date, one- and two-dimensional synthetic seismograms have been produced, and density and velocity information about coal and host sediments has been compiled.

Seismic sections generated from the numerical and physical modelling will be used for an integrated computer interpretation of field seismic data.

Preliminary examination of log data showed that, in many cases, the acoustic impedance contrast is determined primarily by the density contrast between coal and surrounding sediments, and there is little variation in seismic velocity between formations.

One of the more costly elements of coal production in Alberta is the removal of overburden in surface mines. This activity and the associated costs can affect the efficiency of mine operation, the overall costs of Alberta coals and the ability of Alberta coal producers to compete in the international marketplace. Consequently, the competitiveness of Alberta coals can be improved by changing the designs of production pits to lower the costs of overburden removal while simultaneously maintaining safe working conditions.

This year, eight coal mining research projects were underway that addressed concepts of mine design, the effectiveness of designs and the merits of using various robotic and intelligent systems in coal mine environments.

FOOTWALL ANCHORING

SMOKY RIVER COAL LIMITED, GRANDE CACHE

In a project that is unique to the coal mining industry, rock anchors and rock bolts were used to support a steeply dipping footwall in a pit at the No. 9 Mine of Smoky River Coal Limited.

Six hundred mechanical rock bolts and 1 764 tensioned anchors were installed as the pit developed. Eventually, the footwall reached a length of 457 metres and a height of 152 metres, with an angle of approximately 65° to the horizon.

An extensive system of monitoring equipment was installed to assess the overall stability of the slope and provide information about movement and warning of failures occurring along the footwall. This included the use of survey prisms, surface extensometers, borehole extensometers, load cells, piezometers, visual inspections and geological mapping.

Although significant movement of the footwall was detected during the last month of the two-year mining activity, all the coal was successfully extracted from the mine. The footwall failed approximately two months after completion of mining.

Anchoring was accomplished at a cost of approximately 62 per cent of the cost of benching, which is the normal procedure used in such situations.

At Smoky River Coal Limited, the concept of using rock anchors to support a steeply dipping footwall in an open-pit coal mine was successfully demonstrated at less cost than the usual method of footwall benching.

TRIAXIAL TEST DEVELOPMENT

COAL MINING RESEARCH COMPANY, DEVON

The contractor has developed a cost-effective laboratory method of obtaining triaxial test data on the strength properties of rock and coal, which are used in mine design. The developed test method provides three or more times as much information from a single specimen at the same cost as the standard method of triaxial testing.

The project began with a review of previous work, and an examination of the measurement and control techniques being used. Control software was developed for the Coal Mining Research Company's 450 000 kN (1 000 000 lb.) Instron load frame, allowing the system to monitor and control loading rates in keeping with the innovative test method. A multiple peak method of conducting the triaxial test was then developed for rock and coal. The results were verified by comparison with conventional triaxial testing using two Alberta coals, sandstone, mudstone and concrete.

It was demonstrated that multi-stage triaxial test results can be replicated, and experimental error was significantly reduced over conventional triaxial testing on brittle materials. Also, samples can be tested in less time. Further testing of materials showing a wider range of strength, brittleness and microfracturing will be required to establish the method as a standard means of testing versus conventional triaxial testing of rock and coal.

PUBLICATIONS:

Hollingshead, B.G. and A.M. Willott. 1987. ***Multistage Triaxial Test Development.*** *CMRC Report MO 8601.2*

Thornton, S.E. 1986. ***Triaxial Test Development Interim Technical Review.*** *CMRC Report MO 8601.1*

ROBOTICS FOR MINE CONTROL

COAL MINING RESEARCH COMPANY, DEVON

Automation and the use of robotics will improve productivity and worker safety in coal mining, and can play a role in reducing materials handling costs. Consequently, mechanized and intelligent systems should be used whenever repetitive tasks must be executed in a particular order or in response to a well-defined set of circumstances. A good example of this sort of task is the sequence of operations associated with excavation and materials handling — the "truck/shovel" situation. Another example is the monitoring and control of blasthole drilling. If intelligent machines were available, one operator might be able to manage a battery of machines rather than one at a time.

A literature, technology and market survey was undertaken to identify research and development opportunities that could significantly

decrease mining costs under Alberta conditions. It was proposed that a strategy be adopted to develop automated systems using a modular approach, thereby providing short-term benefits on the way to full automation. Three areas were identified by mining companies as being important: coal-waste interface sensing, automated blasthole drill siting and operator-assists for mine vehicles.

PUBLICATIONS:

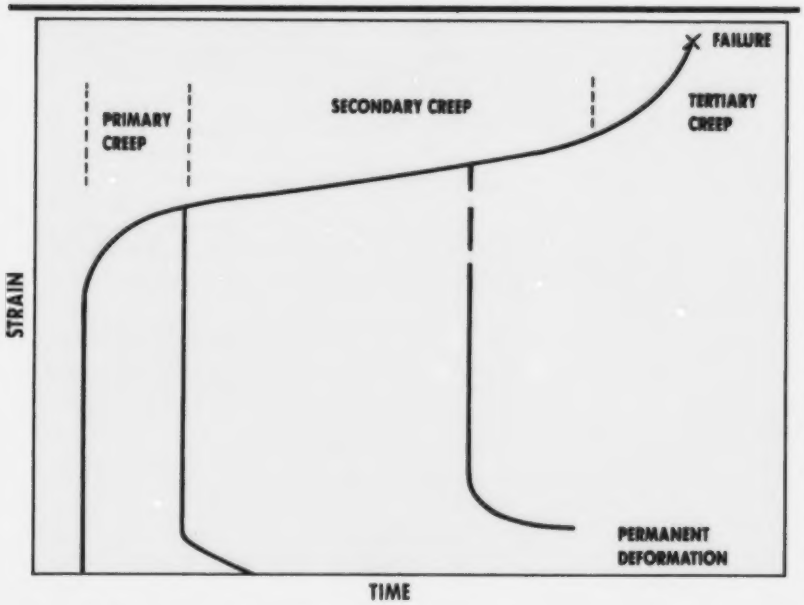
Wilson, R.A. and G.E. Davies. 1986. ***Robotics for Mining Control, A Technical Review.*** *CMRC Report MO 8603.*

Chopiuk, R.G., A.M. Willot and G.E. Davies. 1987. ***Robotics for Mining Control, Phase 2.*** *CMRC Report MO 8603.2*

MINING 2035 WORKSHOP

COAL MINING RESEARCH COMPANY, DEVON

In March 1986, the Coal Mining Research Company (CMRC) completed a three-volume report entitled "Coal Mining in Alberta — 1986 to 2035", which described how coal might be mined in Alberta over the next 50 years.



In this diagram, the relative magnitude of individual creep stages can be observed.

The report included considerable data on related matters, including coal reserves, markets and depletion of the resource. Based on this information, the Mining Division of CMRC developed an Innovative Mining Technology (IMT) program, which identifies the challenges to be met and provides a focus for future research.

A workshop was held at the Coal Research Centre, Devon on February 18, 1987, which used the "2035 Report" to initiate discussions about advanced mining technologies emerging worldwide. Nearly 60 people attended the workshop, representing mining companies, equipment suppliers, electricity producers, consultants, advanced technology companies, governments and universities.

Papers presented by the research community and equipment suppliers emphasized research opportunities offered by automation, monitoring equipment, laser applications and advanced telecommunication techniques. Proceedings of the seminar are available from CMRC's Mining Division.

PUBLICATIONS:

Davies, G.E. 1987. ***Future Mining Technology.*** *CMRC Report MO 8608.3*

Proceedings of a Seminar on Future Mining Technology. *CMRC Report MO 8608.2*

Chopiuk, R.G. and G.E. Davies. 1987. ***Summary Report on the Coal Mining 2035 Workshop.*** *CMRC Report MO 8608.3*

GROUND MOVEMENTS IN COAL MINES

UNIVERSITY OF ALBERTA, (D.M. CRUDEN), EDMONTON

Ground movement models, which were developed to monitor landslides, are being used to predict changes in the strength properties of coal and surrounding rock that might lead to failure and endanger workers in surface mining operations. In this project, which was funded through the Coal Research Grants Program, the contractor is developing conceptual models of the time and deformation dependency of the loss of strength of coal and rock when they fail. Three accelerating creep stages have been identified in coal mine displacement records, providing new models for movement prediction.

A formula relating rock mass displacement rate on a rupture surface to elapsed time has been developed and verified from recorded displacements of a local coal mine.

PUBLICATION:

Cruden, D.M. and S. Masoumzadeh. 1987. ***Accelerating Creep of the Slopes of a Coal Mine.*** *Rock Mechanics and Rock Engineering, 20: 123-135.*

TIME-DEPENDENT BEHAVIOUR OF COAL MEASURE ROCKS

UNIVERSITY OF CALGARY, (R. DAY), CALGARY

With funding provided by the Coal Research Grants Program, the researcher developed a coal mine simulation package to run on a microcomputer. Two important features of the package are interactive pre- and post-processors. A subroutine containing a rate-theory model for material behaviour

has been added to the finite element program. The literature was examined and analysed to produce an extensive data base of creep results. This data base was used to compare the accuracy of predictions from the various available materials models, including the rate-theory model. To confirm the validity of the rate-theory model, the creep behaviour of some specimens was examined under varying temperature conditions.

DEFORMATION AND PROGRESSIVE FAILURE OF OPEN-PIT HIGHWALLS

UNIVERSITY OF ALBERTA, (N.R. MORGENSTERN), EDMONTON

The deformation-stress relationship within an open-pit highwall at the Highvale coal mine is being determined to design mitigative measures in case of failure and predict possible failure zones as mining progresses.

In the field, determinations are being made of highwall deformation, while in the laboratory the physical characteristics of the strata that comprise the highwall are being measured.

A finite element model will be prepared, based on the parameters from the laboratory and stratigraphy obtained from the drilling program and mapping the highwall face. This model will be used to simulate the observed deformations and provide an insight into the processes involved in highwall deformation.

It is expected that measures can be developed to predict possible failure zones and to design mitigative measures. This project is being funded through the Coal Research Grants Program.

ALBERTA COAL GEOLOGY PROGRAM

ALBERTA RESEARCH COUNCIL, EDMONTON

During this first year of a three-year program, a research plan was developed and several preliminary phases were implemented. The program consists of four component projects.

Project 1: Quality of Plains Coal

This project is intended to quantify the degree of variability in coal quality for the Drumheller (Horseshoe Canyon Formation) and Ardley (Paskapoo Formation) coal zones, to develop an understanding of the factors controlling the quality of these coals, and to test predictive models.

Project 2: A Regional Evaluation of Coal Quality in the Foothills and Mountains

A preliminary regional synthesis of coal quality and rank variations had been completed previously for the plains area of the province. This project involves doing a similar, but more comprehensive, study of the coals in the foothills/mountains region to provide information about the properties of coal typical of this area of Alberta.

The objective is to document and provide an understanding of the geological variation in coal quality parameters in the region, and delineate the range of values for major coal quality components on a stratigraphic and geographic basis.

Project 3: Foothills and Mountains Coal Quality — Local Study

Coal companies and planners need to know with what degree of confidence they can interpret existing data on coal quality, which will be documented in the regional study of foothills and mountain coal quality (Project 2).

Research is underway to predict highwall failures, such as in this mine, and develop mitigative measures.

In Project 3, a detailed study of coal quality variations in a structurally deformed, coal-bearing sequence will be made to establish procedures to assess coal quality and make a comparison between coal quality data from different areas of the mountains and foothills.

An understanding of the major geological parameters controlling coal quality will allow the development of predictive models of coal quality variations. Regional geological mapping has provided exploration targets in the past. In the future, detailed coal quality mapping will provide exploration targets in existing coal fields.

Project 4: Data Base Management and Natural Resources Information System

In this project, a data base to be used in the other projects of the program will be designed and maintained. Data produced by the Alberta Research Council Coal Geology Group since 1983 will be consolidated and integrated into the data base, and information will be transferred to the National Resources Information System (NRIS) in a form suitable for use by planners and resource managers.

This project will ensure that information on coal geology, collected by the Alberta Research Council, will be kept in a form that allows continued use in the future. It will be compatible with other Alberta government data base systems, particularly the one used by the Energy Resources Conservation Board.

Coal preparation, also called beneficiation, cleaning or washing, refers to those physical and chemical processes that improve the quality of coal by regulating its size, removing some of its moisture and reducing the mineral matter that produces ash and air pollutants during combustion.

Coal preparation methods have been used for almost as long as there has been a coal industry. Cleaning methods have been steadily evolving into more sophisticated upgrading techniques, largely because modern fuel standards have become more stringent. Experimental work is underway in several countries to find suitable upgrading processes that: remove more ash, inorganic sulphur and nitrogen compounds; effectively treat hard-to-clean coal fines; avoid energy-intensive and costly dewatering and drying; reduce the overall cost of coal cleaning; and change the chemical structure of coal.

Some of these avenues of investigation are being pursued in Alberta, particularly those aimed at upgrading bituminous and subbituminous coals to enhance their energy content and combustion performance characteristics.

COAL BENEFICIATION PROCESS

GULF CANADA CORPORATION AND UNOCAL CANADA, CALGARY

Researchers have developed a process to upgrade the energy content of low rank coals and make them suitable for shipping. This is done by thermally treating them with a low-cost residual petroleum product so that a coating of the residuum (which resembles road asphalt) is left on each dried coal particle. This process also improves the handling properties of the coal and eliminates dust problems.

Residuals derived from heavy oils and bitumen found in large quantities in Alberta are particularly suitable for this process. To date, work has included an intensive laboratory and pilot plant experimental program to study the factors affecting coal upgrading, and the development and operation of a mine-mouth pilot plant at production rates up to 150 tonnes an hour.

In the current program, data obtained from the mine-mouth demonstration at the Obed Mountain Coal Company mine are being evaluated and the process variables are being optimized in a pilot plant at the Coal Research Centre, Devon.

AGGLOMERATION OF SUBBITUMINOUS COAL

MANALTA COAL LTD., CALGARY

Coal agglomeration, a method of producing a low-ash, low-moisture coal by mixing finely ground coal and a liquid hydrocarbon in a water slurry, is being studied as a means of upgrading subbituminous coals.

Based on the results of laboratory-scale agglomeration studies performed at the Alberta Research Council, an economic assessment was made of the agglomeration process, assuming 500 000 tonnes a year of agglomerated product is made from subbituminous coal. Other process assumptions included the use of a 80:20 mixture of Cold Lake heavy oil and diesel oil as a bridging agent, and eventual recovery of the oil mixture from the agglomerated product.

On this basis, it was concluded that it would cost $100 a tonne to produce agglomerated coal from subbituminous coal originating at the Whitewood mine. The best economic results occurred when assumptions about process conditions were altered, such as using subbituminous coal from the Montgomery mine and eliminating oil recovery. Under these conditions, the costs to produce agglomerated coal were reduced to about $59 a tonne.

These costs are substantially higher than indicated by other economic studies, which, except for the cost of the oil, found agglomeration was cost-competitive with coal cleaning and drying.

NUMERICAL ANALYSIS OF PROCESS YIELD LOSSES

COAL MINING RESEARCH COMPANY, DEVON

The operators of coal preparation plants are constantly trying to maximize the production of clean coal because higher yields result in mines being more cost-competitive, both in terms of direct operational costs and the lifetimes of individual mines. This is often difficult to accomplish, however, because of fluctuations in the ash content of the plant feed coal.

To help overcome these difficulties, the technical skills and knowledge of Coal Mining Research Company personnel are being upgraded to enhance the company's ability to perform minesite problem-solving research and identify major losses of fine coal from western Canadian preparation plants.

Exploratory research found that ash fluctuation behaviour can be modelled satisfactorily by using a new branch of mathematics called the Mandelbrot Set or fractal theory. The research also showed that a fairly high sampling rate is necessary to adequately understand and predict the changes to coal quality that occur in an operating coal preparation plant.

PUBLICATION:

McIntosh, P.S. and R.J. Germain. 1986. ***Numerical Analysis of Process Yield Losses, Volumes 1 and 2.*** *CMRC Report 8559-T.*

PROPERTIES OF THERMALLY DRIED COAL

COAL MINING RESEARCH COMPANY, DEVON

Western Canadian mountain coals are friable and produce substantial quantities of fines when prepared. After washing and dewatering, water is retained on the coal surface, particularly in the interstices between the fine coal particles. While excess surface moisture can be removed by thermal drying to levels specified by customers, this tends to degrade the coals, making them dustier.

Conversely, if excess moisture is not removed, it represents additional freight costs because it increases the weight of the cargo, while adding no value. High surface moisture content products are more susceptible to sticking in delivery chutes and may freeze during transit.

Typical metallurgical coals retain between four and six per cent surface moisture after drying; thermal coals, with a lower fines content, retain proportionately less. However, thermal coals have a higher inherent moisture content. The cost of additional drying to reduce the retained moisture plus chemical treatments to control dust, is currently between six and 25 per cent of the product value.

To help achieve higher heating value products while incurring lower drying costs, the Coal Mining Research Company acquired the necessary equipment to pursue research into new or improved methods of coal drying and handling. A pilot plant-scale fluidized bed drier, a Durham Cone coal flow measurement apparatus, adsorption equipment, an environmental chamber and an ASTM dustiness test cabinet were built to CMRC specifications, commissioned, tested and made ready to provide a needed service for the coal industry.

PUBLICATION:

Rashid, M.A., R.J. Germain and D.F. Long, 1986. ***Properties of Thermally Dried Coal, Volumes 1-5.*** *CMRC Report 8565-T.*

WASHERY OPTIMIZATION

COAL MINING RESEARCH COMPANY, DEVON

One cause of coal losses during preparation is inconsistent performance of fine coal separation equipment. To identify these inconsistencies, and to take remedial action, requires the use of sophisticated plant performance-testing techniques. Previous investigations by the researcher found that some of the losses may be simply an artifact of the sampling and analytical methods used by plant operating personnel. Real losses, on the other hand, are likely to occur when the characteristics of feed coal, while within the design capabilities of the preparation plant, fluctuate so as to cause instability in the separation equipment.

Given variable feed conditions, two strategies that might be used to sustain plant optimum performance are:

1) designing coal-processing machines for fluctuations in ash content; or

2) monitoring feed quality continuously and changing equipment settings quickly to compensate for changing feed coal quality conditions.

Both strategies presume knowledge of these parameters, as well as the best method for observing performance fluctuation and analysing the processing system control data. The researchers decided to establish a sound sampling strategy and to find faster and more effective methods of measuring the separation efficiency of fine coal from waste.

Experimental work conducted during 1986/87 evaluated an Australian non-standard method for separation measurement versus the established method using partition curves. While involving less work, the Australian method proved to be less suitable under fluctuating feed coal ash conditions than partition curves for assessing the separator performance.

PUBLICATION:

McIntosh, P.S. and M.J. Kramer, 1986. ***Washery Optimization: Literature Review of Performance Tests.*** *CMRC Report 8659-T.*

An ASTM dustiness test cabinet (top) and a Durham Cone coal flow measurement apparatus are being used in studies of new or improved methods of coal drying and handling.

COAL COMMINUTION

COAL MINING RESEARCH COMPANY, DEVON

Although the carbonaceous material present in western Canadian coals possesses characteristics desired in the marketplace, the overall calorific value of these coals is lowered by the presence of clays which are not readily released during washing.

Several clay-release methods were examined by the researchers; the one having the most promise involved chemical treatment of coal with a carbon dioxide-saturated water solution. Experimentation with a raw subbituminous "B" coal produced a treated product that was coarser

than a conventionally crushed sample and showed a significantly improved liberation of ash. The treated coal was also easier to crush than conventionally treated coal. Further experimentation with a high volatile bituminous "C" type coal produced no significant change in any of its properties, leading the contractor to conclude that the method appeared to be most suited to treatment of subbituminous rank coals.

If the method could be developed to commercial scale, it might reduce capital and power costs, as well as improve product quality, by reducing the amount of alkali metals which are implicated in boiler tube fouling.

PUBLICATION:

Rashid M.A. and D.F. Long. 1986. ***Coal Comminution: Phase I Literature Survey.*** *CMRC Report 8661-1.*

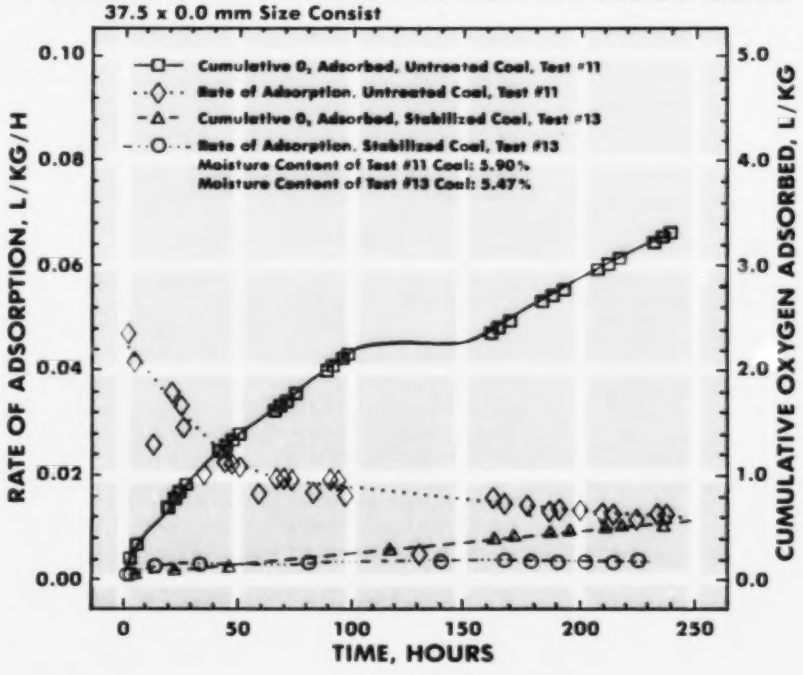
STABILIZATION OF DRIED COAL

COAL MINING RESEARCH COMPANY, DEVON

Low-rank coals are highly reactive and prone to oxidation, especially if they have been dried to below their equilibrium moisture levels. This can lead to spontaneous combustion during storage. It had been established that these coals readily adsorb carbon dioxide. This could represent a potential method for coal stabilization by retarding low temperature oxidation. The objective of this project is to study and quantify this phenomenon. Preliminary results indicate that the adsorbed carbon dioxide layer is affected by diffusion. It was also observed that the effectiveness of the treatment may be influenced by the amount of residual moisture retained in the thermally dried coal.

These results show that carbon dioxide adsorption effectively stabilizes a 38 x 0 mm high volatile bituminous coal, which had been dried to approximately 4 per cent below its equilibrium moisture content.

ADSORPTION OF OXYGEN BY TREATED & UNTREATED HIGH VOLATILE C BITUMINOUS COAL



ADVANCED PROCESSES FOR LOW-RANK COAL

COAL MINING RESEARCH COMPANY, DEVON

Low-rank Alberta coals, such as those found in the plains, have high ash and moisture contents and low calorific values. A number of processes have been described in the literature that might be useful in improving the calorific value and handling properties of Alberta coals, thereby enhancing their marketability.

Researchers are conducting a review of state-of-the-art processes which have the potential to upgrade low-rank coals, and of new and emerging technologies for their utilization.

Selected research and development facilities were visited to review their progress towards commercialization and capability to process samples of western Canadian coals.

The final report recommends processes which should be tested with a view to local development. Discussions with interested coal producers are planned.

PUBLICATIONS:

Adamson D.G. et al 1986. ***Advanced Processes for Low Rank Coal — Volume 1 — Literature Survey.*** *CMRC Report 8669-1.*

Butcher S.G. 1987. ***Advanced Processes for Low Rank Coal — Volume 2 — R&D Facilities Visits.*** *CMRC Report 8669-2.*

Adamson D.G. and S.G. Butcher. 1987. ***Advanced Processes for Low Rank Coal — Volume 3 — Final Report.*** *CMRC Report 8669-3.*

The more that is known about combustion characteristics of individual types of coal, the more likely it is that sales can be made to those customers whose specific requirements closely match the combustion properties of Alberta coals. In particular, some emerging combustion technologies achieve optimum performance by using coals having narrowly specified properties. This means that detailed studies of coal combustion characteristics are necessary. This need is further increased by a growing tendency on the part of users to burn blends of coals. Consequently, the Alberta Office of Coal Research and Technology has initiated several coal combustion studies, in conjunction with the coal industry and in collaboration with end users, to encourage producers and users to share their knowledge and better understand performance requirements and characteristics.

INTERNATIONAL ENERGY AGENCY COAL COMBUSTION SCIENCE

NETHERLANDS ENERGY RESEARCH FOUNDATION, PETTEN

The International Energy Agency currently operates a program of research, development and demonstration of coal combustion sciences. Annex II of this international, co-operative activity is planned as a three-year program jointly funded by Canada, the Netherlands and the Federal Republic of Germany. The Canadian contribution to this program is divided among the Canada Centre for Mineral and Energy Technology (CANMET), the Canadian Electrical Association and the Alberta Office of Coal Research and Technology. The objective of the program is to achieve effective and economic combustion of a great variety of coals, while minimizing environmental impacts. To achieve this objective, fundamental studies and semi-industrial scale experimental research is carried out at the International Flame Research Foundation (IFRF), IJmuiden, Netherlands.

The research program is focusing on understanding the mechanisms for the reduction of sulphur oxide emissions through direct sorbent injection, the reduction of nitrogen oxide emissions through staged combustion, characterization of combustion properties of various types of coal and transformation of mineral matter during combustion in relation to combustion system slagging, fouling and fly ash emission. A strong emphasis has been placed on applicability of the developed technology to conventional, pulverized coal-fired boilers.

The experimental work during the past year included the design and testing of a proprietary, aerodynamically air-staged burner for low NO_x combustion of coal. The development of this burner has entailed the use of numerical modelling of the aerodynamics of coal flames, laboratory studies of the devolatization and char combustion properties of several coals, and the testing of prototype burners at a scale of 2.5 MW thermal output. Reduction of NO_x emissions to less than 300 ppm at zero per cent oxygen has been achieved with greater than 98 per cent carbon burnout. The current emphasis of the project is on the development of design tools necessary for scale-up of the burner, and testing a range of burner sizes using three different coals.

COMBUSTION PROCESS RESEARCH

ALBERTA RESEARCH COUNCIL, NISKU

Despite several decades of coal combustion research, certain fundamental combustion phenomena are not well defined, and the combustion properties of a coal cannot be confidently predicted without a series of characterization studies of varying size up to full-scale burn tests.

To aid in the training of Alberta Research Council staff, and to plan and develop coal combustion research and characterization facilities, a program of site visits, temporary staff placements and conference attendance was undertaken this year.

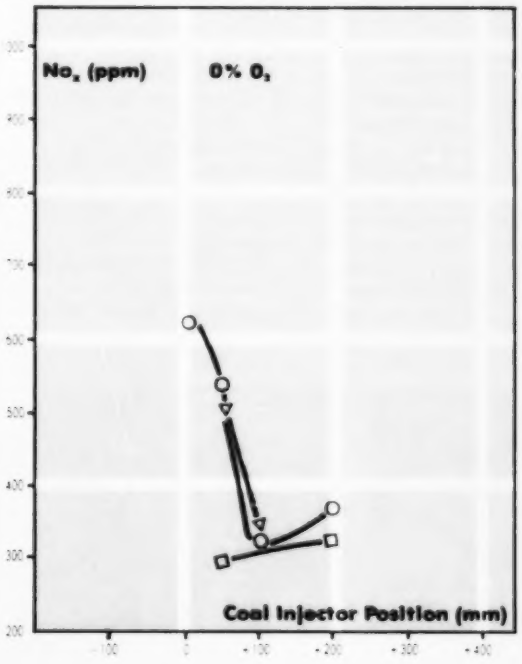
The following conclusions were drawn:

1) a pilot-scale combustor is required to assess flame stability, fouling and electrostatic precipitator performance;

2) small-scale facilities can be used to assess coal ignition and char burnout properties;

3) characterization or simulation experiments demand experienced personnel, a reliable coal sample bank and a data base of known properties for several coals;

4) further experimentation is needed on volatiles, combustion kinetics and mineral matter transformation;



A proprietary burner, designed to produce low NO_x emissions when coal is burned, was tested this year. Here, the effect of the coal injector position on NO_x emissions is shown for three sets of operating conditions.

5) new, non-intrusive measurement techniques are needed to study flames in regions of turbulent flow; and

6) fundamental experimentation at bench, pilot and prototype scale is needed to establish the proper scale-up factors.

PUBLICATION:

Chambers, A.K. 1987. ***Current Experimental Techniques Applied in the Study of Coal Combustion.*** *Alberta Research Council.*

COMBUSTION CHARACTERISTICS OF ALBERTA COALS

ALBERTA RESEARCH COUNCIL, NISKU

As new combustion technologies emerge which require coals having specific combustion characteristics, there is a growing need to identify those Alberta coals most suited to these technologies and to better understand the behaviour of Alberta coals when they are burned.

A review of the literature revealed that the presence of large amounts of inertinite macerals in coal may contribute to the production of unburnt carbon in the boiler fly-ash. Consequently, four Alberta coals of three different ranks (low volatile bituminous, high volatile bituminous and subbituminous "B"), together with vitrinite and inertinite concentrates from the same coals, were tested for their combustion reactivity in the Alberta Research Council's entrained-flow combustor, a thermogravimetric analyser (TGA) and in a single-particle combuster at Sandia National Laboratories, Livermore, California. The structure of partially combusted chars was also examined by a scanning electron microscope (SEM).

The investigations showed:

1) the inertinite fraction had a lower volatile matter and higher ash content than the parent coal, while vitrinite with a similar volatile matter content produced less ash;

2) slow pyrolysis chars observed in the TGA at low temperatures exhibited low activation energies. For three of the four coals, the inertinite fraction had a lower reaction rate, as measured on the TGA, than the parent coal or the vitrinite;

3) reaction rate varies with burnoff in a way that is characteristic of each individual coal;

4) single-particle, entrained-flow combustion experiments conducted at the Sandia National Laboratory demonstrated that high volatile bituminous and subbituminous coal chars and maceral fractions burn at the diffusion limit, while the low volatile bituminous coal and its macerals burned at the same rate in a regime of combined pore diffusion and kinetic control; and

5) examination of scanning electron micrographs from partially burned particles indicated that some inertinite macerals retain their original structure during the combustion process. Relatively unreactive coal particles form thin-walled spheres, while reactive coals form a porous, sponge-like structure during combustion.

The results suggest that it may be possible to relate the inertinite content to the amount of unburnt carbon that remains in the fly-ash. Several unresolved problems remain, however, and the effect of reaction temperatures on the combustion of individual coal particles requires further study.

PUBLICATIONS:

Chambers, A.K., K.J. Knill and D.E. Ungarian. 1987. ***Combustion Properties of Macerals from Four Alberta Coals.*** *Alberta Research Council.*

Knill, K.J. 1987. ***Evaluation of the Combustibility of Hydropyrolysis Chars.*** *Master's Thesis, University of Alberta, Alberta Research Council.*

PREDICTION OF COAL COMBUSTIBILITY

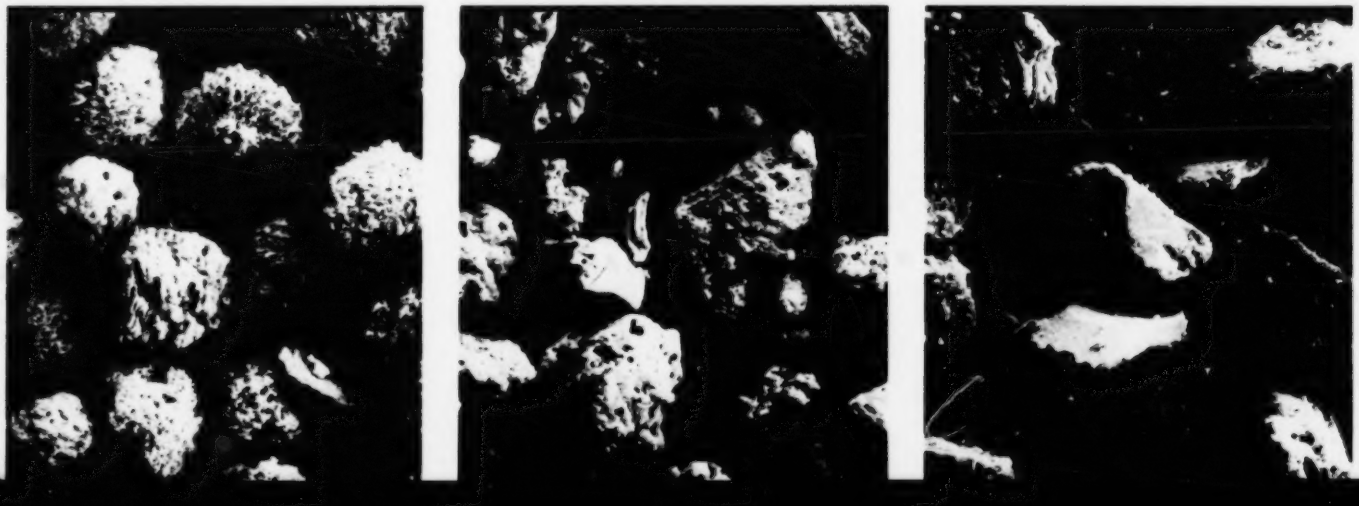
ESSO RESOURCES CANADA LIMITED, CALGARY

During 1986-87, laboratory-scale combustion testing of bituminous coals verified an empirical model relating carbon burnout of coal to specific feed coal properties, principally coal rank and composition. The model which has been developed from those tests is purely empirical and serves only to demonstrate that the combustion of coal can be understood and rationalized, provided that due care is taken in evaluating feed coal properties.

To complement the combustion work, ignition tests were carried out to examine the influence of combustion temperatures on overall burnout. The time required for different coals to reach ignition temperature under similar conditions is highly variable. This is a crucial element in understanding the empirical combustion model. As might be expected, coal rank also greatly influences ignition.

The results from the year's work have clearly demonstrated that geochemical

The physical structure of partially combusted coals is revealed by these scanning electron micrographs of (left) partially combusted char from high reactivity coal, (middle) partially combusted char from low reactivity coal, and (right) original coal particles.



principles are applicable to coal combustion, and that continued developmental work along these lines has potential applications in the areas of resource evaluation and thermal coal utilization.

COMBUSTIBILITY OF AGGLOMERATES

ALBERTA RESEARCH COUNCIL, DEVON

The flame stability and carbon burnout characteristics of agglomerated products from two bituminous and two subbituminous coals were compared with those of certain U.S. high volatile bituminous coals used by Ontario Hydro.

Laboratory-scale combustion tests were carried out on the four samples, as well as the two parent coals and a U.S. coal sample forwarded by Ontario Hydro. The tests included thermogravimetric analysis, ignition tests and entrained flow combustion tests.

Results indicated that heat-treated agglomerates burn more rapidly than the reference U.S. coal. One of the agglomerated subbituminous coals was burn-tested last year at Ontario Hydro's coal combustion research facility and was found to have a high heating value and good burning characteristics. Those same properties were noted during this year's laboratory-scale combustion test.

PUBLICATION

Knill, K.J. and D.E. Ungarian. 1987. ***Comparative Evaluation of the Combustibility of Alberta Coal Agglomerates.*** *Alberta Research Council.*

CAUSES OF SPONTANEOUS COMBUSTION OF WESTERN CANADIAN COALS

UNIVERSITY OF CALGARY, (F.W. BACHELOR), CALGARY

The reaction between oxygen and coal under ambient conditions, which leads to spontaneous combustion, is not sufficiently understood.

The role of moisture and peroxides in this process has received the most attention by other researchers. This study, which is funded through the Coal Research Grants Program, concentrates on three other potential contributors to this phenomenon: coal macerals, trace metals and chemical radicals. These contributors, in combination with externally introduced water and oxygen and optimum environmental conditions, provide all the necessary requirements for spontaneous combustion to occur in coal.

The results of ignition tests and reflectance microscopy investigations (shown here) have demonstrated that correlations exist between the geochemistry of coal and combustion characteristics.

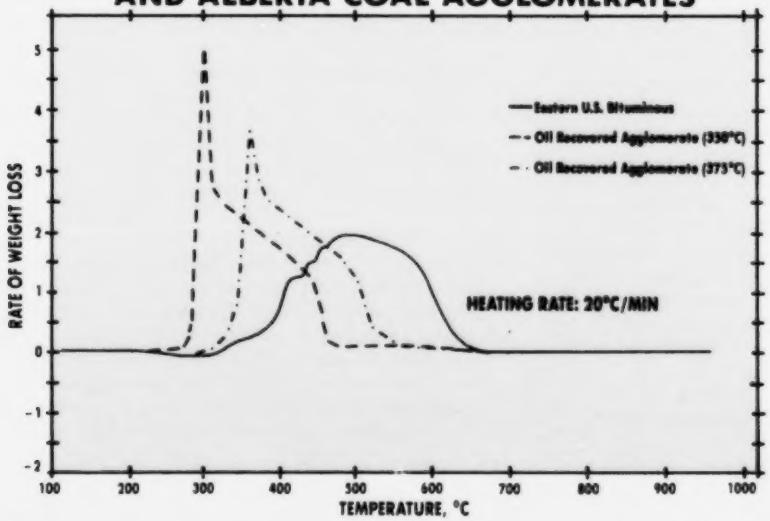
TECHNICAL ASSISTANCE TO THE ALBERTA OFFICE OF COAL RESEARCH AND TECHNOLOGY

ALBERTA RESEARCH COUNCIL, DEVON

A research officer from the Alberta Research Council was seconded to the Alberta Office of Coal Research and Technology to help define a joint industry government coal combustion research program, and to participate on technical committees related to the International Energy Agency (IEA) Coal Combustion Science Project Agreement, Annex II.

Three projects were defined with the help of representatives from the coal-producing companies in Alberta, and companies with coal production interests in Alberta and elsewhere in western Canada, as well as boiler manufacturers, utilities, the federal government, and the governments of British Columbia and Saskatchewan. These projects were: coal use for enhanced oil recovery, coal gasification technology research and dry sorbent injection.

THERMOGRAVIMETRIC ANALYSIS COMBUSTION PROFILES OF EASTERN BITUMINOUS AND ALBERTA COAL AGGLOMERATES



A meeting of the Canadian Technical Committee of the International Energy Agency was attended, a preliminary overview of gasification technologies and the gasification behaviour of Alberta coals was prepared, and the International Flame Research Foundation (IFRF) facilities in IJmuiden, the Netherlands were visited. Also, advice was provided on two studies: coal use for enhanced oil recovery, and the gasification of western Canadian coals. Both studies were subsequently funded jointly by the Office and two groups of coal companies and electrical power utility companies.

Over the next 30 years, production of conventional crude oil from Alberta's established oil fields is expected to decline well below current levels. The rate of decline will depend on a number of factors, such as world oil prices and demand, but eventually it will become necessary to produce more synthetic crude oil from Alberta's oil sands, heavy oil and/or coal. Although the economics of producing oil in this manner are unattractive because of depressed oil prices, at least there is an abundance of raw materials. Alberta's proven reserves of subbituminous coals, for instance, could provide enough synthetic crude oil to satisfy domestic consumption for at least the next century, assuming a suitable and economic liquefaction process can be developed to convert coal to petroleum substitutes.

One conversion concept that is showing some promise, and has been studied extensively in Alberta, involves co-processing of coal and heavy oil or bitumen. Not only does it provide a method of producing synthetic crude oil from coal, but it may also prove to be useful for upgrading heavy oil. This and other potential liquefaction processes are under development, as are methods of analysing the products of liquefaction reactions. The level of research in Alberta on liquefaction work has led to considerable collaboration among the various participants at Alberta Research Council and the University of Alberta.

PYROSOL PROCESS DEVELOPMENT

CCLC TECHNOLOGIES INC., EDMONTON

The first full year of co-processing experimental work was completed on the PYROSOL process, a liquefaction concept that originated in the Federal Republic of Germany. In addition to work carried out in Alberta, complementary experiments were conducted in Germany.

A 2 kg/hr co-processing hydrogenation unit and a 1.3 litre delayed coker were successfully commissioned and used to evaluate PYROSOL. Two significant conclusions arose from this year's work:

— Experimental results from low-severity hydrogenation, followed by delayed coking, confirmed some of the basic assumptions of the process. A high pitch conversion could be obtained while maintaining low hydrogen consumption. The mild severity conditions used, together with the co-processing feed, posed no problems with the operation.

— In evaluating the first stage, it was determined that a high-yield process, comprising solubilization followed by hydrogenation (the "CCLC Process"), may be suggested for certain types of co-processing feed.

The first set of experimental work evaluated different fractions of heavy oil feedstocks with coal. The results showed that simply removing the light ends from Cold Lake bitumen before mixing with coal provided at least five weight per cent greater net distillable oil yield when compared to vacuum distillation or prehydrogenating the bitumen before slurrying with coal. However, overall economic considerations of feedstock cost led CCLC Technologies Inc. to pursue Cold Lake vacuum bottoms in all remaining tests.

The next level of work determined the necessary conditions in the first stage hydrogenation to produce a desired pitch conversion. Variation of the reaction severity parameters of temperature, pressure and reactor residence time provided pitch conversion rates varying between 30 and 88 weight per cent based on moist, ash-free (maf) feed. In all severity tests, the feedstock was 35 weight per cent maf Vesta coal, two weight per cent iron oxide catalyst and Cold Lake vacuum residual.

Coking of the first stage reactor discharge to evaluate the net increase in the overall distillable oil yield from the process was a primary focus of the year's work. In the PYROSOL process, the distillable oil yield was split between low severity hydrogenation and hydrocoking, with the overall yield equivalent to or greater than the traditional high severity hydrogenation processes. The +380°C fraction distilled from the hydrogenation reactor products was processed further in a delayed coker. The results of these preliminary tests are very encouraging.

Zeton Inc. of Burlington, Ontario, was contracted to design, obtain, construct and install a 227 kg (1/4 ton) per day continuous, two-stage hydrogenation unit, followed by a pressurized delayed hydrocoker. The unit was to be installed at Alberta Research Council's high pressure laboratories in Nisku by August 1987.

GfK-Gesellschaft fur Kohleverflussigung mbH of West Germany continued to explore the PYROSOL technology for liquefaction of German hard coal. Besides the development of a continuously pressurized hydrocoker, their program centred on the construction of an integrated 10 kg/h (22 lb./hr.) test facility consisting of a hydrogenation reactor followed by the hydrocoker.

Several successful test runs were conducted during the year. The data confirmed the basic advantages of the PYROSOL process when compared to the high severity traditional processes normally used for coal liquefaction.

LIQUEFACTION PROCESS EVALUATION

ALBERTA RESEARCH COUNCIL, DEVON

Coal liquefacton plants are relatively complex hydrocarbon refineries which normally include solids handling and disposal systems, large-scale hydrogen production units, and product gas and wastewater cleanup facilities. Because few such plants have ever been built on a commercial scale, it is difficult to assess the economic viability of various liquefaction processes. Similarly, the costs of undertaking detailed engineering studies of process options can be prohibitive. Therefore, it was decided that a simple evaluation technique should be developed to estimate relative process economics and identify promising options.

In this study, an economic evaluation strategy was chosen, which consisted of establishing a hypothetical "base case" multi-stage

liquefaction process that co-processes coal and bitumen under moderately severe conditions without a recycle stream. Mass and energy balances were then calculated, using data derived from the Alberta Research Council bench-scale liquefaction apparatus.

A discounted cash flow analysis, return-on-equity business simulation model was used to generate financial information. A simple process "figure of merit" was then proposed to provide a relative ranking of three different liquefaction processes, based on liquids yield, product quality, process severity and process complexity.

Three liquefaction processes were evaluated. They were: the multi-stage base case; a more severe hydrogenation process; and the PYROSOL co-processing system. The model was then validated by using the traditional discounted cash flow analysis. The research team concluded that PYROSOL was the most attractive alternative and that the model was a suitable preliminary evaluation tool for ranking alternatives for further study.

PUBLICATION:

Aitchison, D.A. and G. Hagerty. 1987. ***Preliminary Economic Evaluation of a Multi-stage Coal/Heavy Oil Co-processing Concept and Development of a Simple Process Evaluation Model.*** *Alberta Research Council.*

NEW LIQUEFACTION PROCESSES

ALBERTA RESEARCH COUNCIL, DEVON

Most of the currently known methods for conversion of coal to synthetic crude petroleum have been thoroughly studied over the last 50 years. Because these first generation processes involve high temperatures and pressures, they are described as "high severity" processes, which impose an energy penalty and demand large capital investments in physical plants and machinery.

In this project, the objective was to identify physical and chemical processes that may permit conversion of coal to petroleum-like substances under reaction conditions that are less severe than normal.

Following a review of numerous alternatives, four approaches were selected for study. They were: coal solubilization (the process of converting coal from the solid phase to the liquid phase) with supersolvents; coal solubilization with hydrogen-enhanced bitumen; H_2/H_2S reducing gas systems; and coal solubilization by alkylation methods.

A supersolvent, N-methylpyrollidone, successfully solubilized up to 72 weight per cent of the coal at 350°C and ambient pressure. Solvent decomposition and recovery were identified as major obstacles to development of a process. Hydrogen-enhanced bitumen was produced by catalytic hydrogenation and then used as a solvent for coal. High coal conversions to good quality liquid product were achieved at approximately 400°C and 6.9 MPa hydrogen pressure. Although these conditions are not as low as those for the supersolvent work, the pressure is well below the 14-21 MPa of conventional processes. Alkylation techniques at mild severity were unsuccessful with a maximum coal conversion of 27 weight per cent being achieved. Two ionic hydrosulphide additives were evaluated for improving coal solubilization. However, no substantial differences in coal conversion or product distribution were found.

PUBLICATIONS:

Aitchison, D.A., P. Clark, R. Hawkins, L. Logan and T. Ohuchi. 1986. ***Coal Solubilization with Supersolvents.*** *Alberta Research Council.*

Aitchison, D.A., P. Clark, T. Ohuchi, R. Hawkins and L. Logan. 1987. ***Coal Solubilization with Sulfur Additives.*** *Alberta Research Council.*

Aitchison, D.A., P. Clark, R. Hawkins, L. Logan and T. Ohuchi. 1987. ***Coal Solubilization by Alkylation.*** *Alberta Research Council.*

Aitchison, D.A., P. Clark, R. Hawkins, L. Logan and T. Ohuchi. 1986. ***Coal Solubilization with Hydrogen Enhanced Bitumen.*** *Alberta Research Council.*

Clark, P.D. 1986. ***New Liquefaction Processes: A Review of Low Severity Liquefaction Concepts.*** *Alberta Research Council.*

CHARACTERIZATION OF COAL LIQUIDS

ALBERTA RESEARCH COUNCIL, DEVON

Most published coal liquefaction process evaluations do not satisfactorily describe product quality, nor do they explain the chemical changes that occur in process fluids at each step in processing. This project is intended to fill this need. An analysis tree has been developed and specific tests for important compounds in bitumen are under study. A parallel testing sequence will be carried out for solubilized coal. These tests will be codified into a testing protocol and further tested for data integrity. A series of laboratory-scale experiments will be conducted on co-processed liquids to identify reaction pathways. In later phases, the liquid characterization protocols will be used to monitor the quality of process fluids at each step.

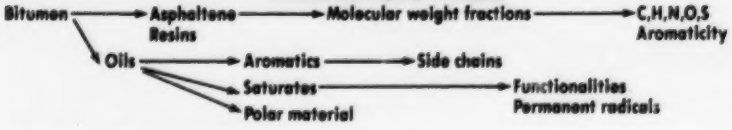
The concept of "product quality" is not well defined. Assuming the petroleum refining industry is the potential customer for coal-derived syncrudes, the crude petroleum assay technology used by refiners would appear to be a logical method of valuating coal liquids. To learn how conventional crude and syncrude refiners place a value on feedstocks, the project team visited three refineries in the Edmonton area.

While the various refiners use different methods to arrive at prices, all of them agreed that the most important characteristics for a crude petroleum are: (1) a cetane number above 35; (2) minimal aromatic content, because straight-chain hydrocarbons produce the best products; and (3) minimal nitrogen content (no greater than 10 ppm in the naphtha fraction).

Following the meetings, the research team concluded that the highest priority for research was the development of a small sample substitute for the standard cetane number test. This new test, to be known as the cetane index, is being

developed using the nuclear magnetic resonance (NMR) response of a substance, correlated with its standard test cetane number. At year's end, samples of the range of substances of interest had been assembled and their NMR responses measured. Standard test results were being collected wherever possible, or were being measured at the same time.

ANALYSIS TREE



FUNCTIONAL GROUP ANALYSIS OF COAL LIQUIDS

UNIVERSITY OF ALBERTA, (M.R. GRAY), EDMONTON

The process of upgrading coal into a more useful liquid feedstock involves a formidable sequence of primary and secondary reaction steps. Coal-derived liquid hydrocarbons are so complex that it is not possible to identify and quantify every chemical compound.

A characterization classification system is required which is easy to implement, describes major reactive structures adequately and is flexible. It must bridge the gap between detailed chemical analysis and physical methods normally used by researchers, e.g., boiling point distribution.

This research project, funded by the Coal Research Grants Program, was designed to develop a structural description of coal liquids which would be suitable for kinetic modelling by using a technique called Functional Group Analysis. This method provides a measure of the concentration of significant chemical structures. Initially, important coal conversion processes were identified and coal liquid samples were obtained. Then, analytical methods specific to coal liquids were developed. This has permitted evaluation of the quality of liquefaction solvents and monitoring of the roles and interrelationships of different fractions during product formation. This knowledge is being applied in designing experimental approaches for coal liquefaction research.

HYDROPROCESSING OF COAL-DERIVED LIQUIDS

UNIVERSITY OF ALBERTA, (I.G. DALLA LANA), EDMONTON

When a complex organic mixture such as a coal-based liquid is upgraded by hydrogenation, a variety of compounds can react chemically and undergo change. A very complicated network of primary and secondary reactions emerges; a situation which is impossible to describe given current uncertainty about the chemistry involved. Any attempt to describe the kinetics of the reaction requires identification of specific (or lumped) reaction steps and determination of a rate function and its kinetic parameters for each step incorporated within the kinetic model. No satisfactory approach to this condition of uncertainty has been developed to date for coal-based liquids.

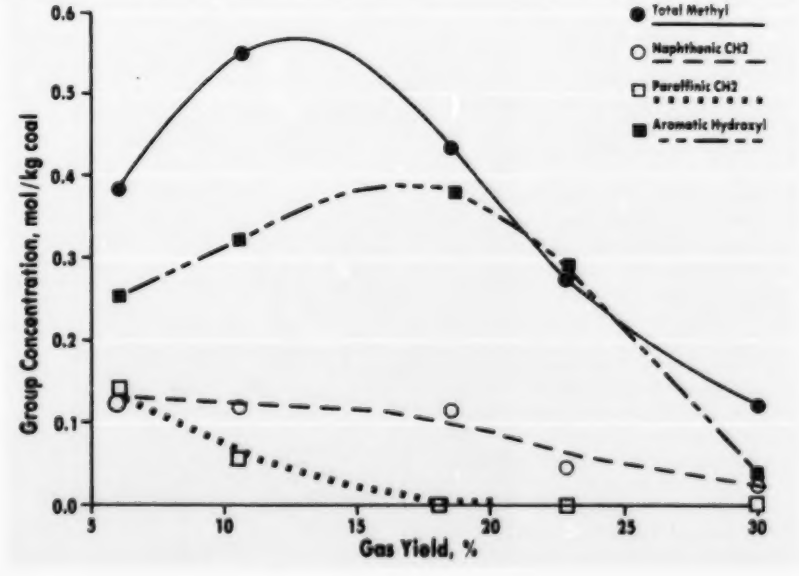
This year, equipment was acquired to:

1) begin investigating the catalytic chemistry of hydroprocessing of coal-derived liquids by employing functional group analysis results and model compound studies;

2) establish performance criteria and standards for upgrading Alberta coal liquids;

3) determine experimental performance data for upgrading a coal liquid which, together with functional group analysis, will facilitate rational kinetic modelling; and

4) evaluate the role of Ni-Mo-Al_2O_3 catalysts in hydrodenitrogenation and hydrodesulphurization of model compounds, particularly with reference to defining diffusional limitations.



This figure, showing the concentration of structural groups as a function of process severity (gas yield) illustrates how functional group analysis can be used to optimize liquefaction reactions.

It is proposed that the combination of functional group analysis as applied to the interpretation of catalytic hydroprocessing of coal liquids, and of chemical reactivities of functional groups as a function of process conditions, should enable development of sound kinetic models. These might provide the basis for "a priori" design of a reactor to catalytically upgrade an arbitrary coal liquid of given functional group composition.

ISOTOPIC STUDIES OF COAL/ BITUMEN CO-PROCESSING

UNIVERSITY OF ALBERTA, (K. MUEHLENBACHS), EDMONTON

Because the carbon derived from coal, when coal and bitumen are co-processed, can be measured by isotope mass balance techniques, the fate of the coal component during secondary upgrading of separated fractions of product from first stage co-processing can be followed. Also, isotopic monitoring can be extended to include tracing of nitrogen and oxygen elements during co-processing. This is important because the heteroatom content in coal-derived liquids must be lowered by a factor of ten for processing in conventional oil refineries.

Earlier in this project, the isotope mass balance technique was successfully used to monitor the amount of coal incorporated into synthetic oils produced in a wide variety of autoclave co-processing runs.

This year, the results show that the addition of coal increased the distillate yield over that obtained by processing bitumen alone. As the coal concentration increased, more of it was incorporated into the synthetic liquid. However, with coal to bitumen ratios greater than 4:1, the amount of insoluble material increased, suggesting that a saturation limit of coal in the co-processing feed slurry exists. The isotopic tracing technique appears to be a useful tool for monitoring coal/bitumen co-processing research and should be considered for use in coal conversion research programs.

PUBLICATIONS:

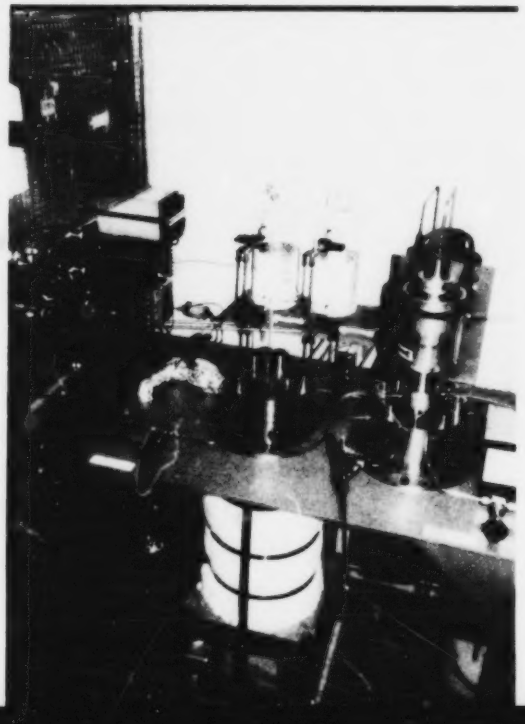
Steer, J.R., T. Ohuchi and K. Muehlenbachs. 1987. ***Efficacy of Coal-Bitumen Co-processing as Determined by Isotopic Mass Balance Calculations.*** *Fuel Processing Technology. 15:429-438.*

Ohuchi, T., J.R. Steer, K. Muehlenbachs and D. Carson. 1986. ***Influence of Slurry Composition on Coal Solubilization as Determined by C^{13} Mass Balance Calculations.*** *Proc. 36th Can. Chem. Eng. Conf., Sarnia, Ontario.*

Steer, J.R., K. Muehlenbachs and T. Ohuchi. 1986. ***Isotopic Measurement of the Proportion of Coal Liquefied by Co-processing.*** *69th Canadian Chemical Conference, Saskatoon, Saskatchewan, June 1-4.*

Steer, J.R., T. Ohuchi and K. Muehlenbachs. 1986. ***Quantitative Determination of the Amount of Coal Incorporated into Synthetic Oil.*** *Proceedings First International Rolduc Symposium on Coal Science, Rolduc, The Netherlands, April 28 - May 1.*

Laboratory experiments using this apparatus are underway to extract hydrocarbon liquids from coal.



SUPERCRITICAL GAS EXTRACTION OF COAL

UNIVERSITY OF ALBERTA, (N. BERKOWITZ), EDMONTON

In this project, funded by the Coal Research Grants Program, the researcher is investigating the use of supercritical gas extraction techniques for removing liquid hydrocarbons from coal before it is consumed as a basic energy source. The technique may offer substantial advantages over conventional low-temperature carbonization or flash pyrolysis as a means for liquid hydrocarbon production from coal. Particular interest centres on extraction with water in the presence of carbon monoxide.

To establish optimum conditions, extractions are being conducted with varying sweep rates at temperatures ranging from 400 to 425°C and at pressures between 14 and 25 MPa. The effects of disposable and alkali-promoted catalysts are also being examined.

PUBLICATION:

Berkowitz, N. and J. Calderon. 1987. ***On "Partial" Coal Conversion by Extraction with Supercritical H_2O.*** *Fuel Processing Technology. 16: 245-256.*

By the mid-1990s, it is expected that production of a variety of synthesis gases (including hydrogen) by gasifying coal will become a significant activity. Here, as with liquefaction, it is assumed that an economically viable gasification process can be developed.

Research in other countries suggests that the next generation of coal-fired electricity-generating plants will likely use the Integrated Coal Gasification Combined Cycle (IGCC) process, which uses coal gasification followed by gas clean-up to produce a fuel for a gas turbine, and generates air emissions far below those produced by current coal-fired power plants. Consequently, several research investigations are now underway to transform Alberta coal into clean, useful fuel and determine the characteristics that make coals suitable for IGCC technology.

GASIFICATION OF WESTERN CANADIAN COALS

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS

In recent years, coal research groups and utilities in several countries have been developing processes to gasify coal and use the gases that are produced as fuels, particularly in electricity-generating systems. Out of this effort has come a concept known as Integrated Coal Gasification Combined Cycle (IGCC), which represents a method of using coal to generate electricity while limiting the production of emissions to only a fraction of those produced by current coal-combustion technology.

A study was made of existing coal gasification technologies, applications of these technologies, and the prospects of this technology being used in Pacific Rim countries that are markets for Alberta coal.

While the study identified four general applications of gasification systems, it was concluded that IGCC has the most promise in the near future. Technological developments for use of the technology in Japan are sufficiently advanced that Alberta coals should be made available to Japanese researchers for testing.

Based on the findings of the study, a Canadian Coal Gasification Technology Research, Development and Demonstration Program was created and is being facilitated by the Alberta Office of Coal Research and Technology and CANMET to undertake research on various aspects of IGCC systems and build a 60 MW prototype plant in Alberta by the mid-1990s.

GASIFICATION PROCESS RESEARCH

ALBERTA RESEARCH COUNCIL, DEVON

It has become increasingly important to have a locally available pool of expertise available to industry to assist with the evaluation of competing gasification technologies.

The Coal and Hydrocarbon Processing Department of Alberta Research Council is training a team of scientists and engineers in the fundamentals of coal gasification theory, and plans to place them in active research centres in both Canada and elsewhere to become well-versed with the technology. Testing and research facilities are being developed at the same time, which will assist Alberta Research Council in developing competence in this field.

CORROSION IN GASIFICATION SYSTEMS

UNIVERSITY OF CALGARY, (W.J.D. SHAW), CALGARY

The electrochemical behaviour of certain select alloys exposed to coal gasification environments is being investigated, and studies are underway to measure the effect of very thin coatings of various materials which might act as catalysts or poisons and thus control corrosion reactions.

Until corrosion mechanisms have been identified, there is no logical way in which a material can be designed or protected in coal gasification environments.

It has been established that stainless steels are dependent upon an anodic corrosion control mechanism, but mild steel under the same conditions reacts to cathodic corrosion control. This project is being funded through the Coal Research Grants Program.

GASIFICATION PROPERTIES OF ALBERTA COALS

ALBERTA RESEARCH COUNCIL DEVON

Fuel gas was first produced from coal in the early nineteenth century. From then until the 1930s, coal gasification was routinely used to produce fuels and chemical feedstocks until natural gas replaced coal in these markets. Recent improvements in coal gasification and gas turbine technology have made coal gasification technologies more efficient, environmentally acceptable, and economically feasible for electrical power generation. Side streams from these same Integrated Coal Gasification Combined Cycle technologies have the potential of providing low-cost chemical feedstocks for the synthesis of plastics, hydrogen-based processes, carbon dioxide-based processes and methanol production. The same technologies can be used to produce synthesis gases, hydrogen and carbon dioxide.

It is critically important that the behaviour of Alberta coals in the various gasification technologies be known if Alberta utility companies are to make wise choices for the next generation of power plants, and Alberta coal producers are to effectively market their products elsewhere in the world.

Of the three major coal types in Alberta — subbituminous, high volatile bituminous and low-to-medium volatile bituminous —

the subbituminous plains coals and the foothills high volatile bituminous coals have been shown to be extremely reactive in combustion, while low volatile bituminous coals have lower combustion reactivity. Because gasification reactions are similar to combustion, similar differences in the relative gasification reactivities of Alberta coals are anticipated.

In this investigation, an existing thermogravimetric analyser is being modified to allow operation at high pressures, and to measure the reactivity of several Alberta coals and a benchmark coal from the United States. By including the U.S. coal that has been well characterized and described in the literature, it should be possible to predict the relative reactivity of Alberta coals in full-sized gasifiers.

GASIFICATION BEHAVIOUR OF ALBERTA COALS

ALBERTA RESEARCH COUNCIL, DEVON

There are three main generic gasification processes, classified according to their reaction vessel types: fixed bed, fluidized bed and entrained flow.

Currently, efforts are directed towards identifying suitable laboratory-, bench- and pilot-scale gasification facilities, which can be used to test the three major types of Alberta coals in each of the three gasification processes over the next 15 months. It is expected that results from these experiments and from thermogravimetric kinetic rate experiments can be combined into a general purpose numerical process model, which can be used in the technical evaluation of the various reactor types with each type of coal.

ENVIRONMENT

Although environment issues must be addressed in each of the projects funded by the Alberta Office of Coal Research and Technology, two investigations this year were aimed specifically at reducing the negative effects of coal-related activities on the environment.

LOW NO_x SO_x BURNER

TRANSALTA UTILITIES CORPORATION, CALGARY

The TransAlta Low NO_x/SO_x slagging combustor eliminates most nitrogen and sulphur oxides from gaseous combustion products before they can escape into the environment. It is claimed that this combustor can be retrofitted to a conventional power plant for less cost than add-on technologies such as flue gas desulphurization. This technology was originally developed by Rockwell International in California.

During 1986/87, cost estimation and scheduling were completed in preparation for a prototype demonstration of the Low NO_x/SO_x burner. Also, experimental work on sulphur removal from bituminous coal was undertaken using Rockwell International's pilot-scale burner in California.

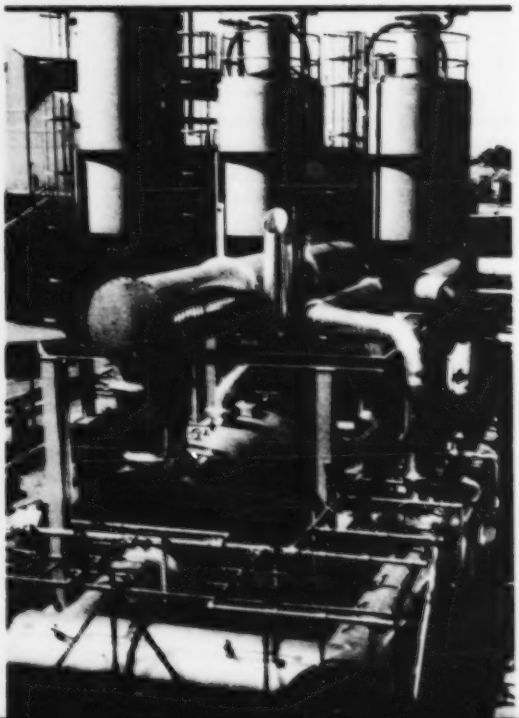
The experimental SO_x reduction program showed that sulphur is efficiently captured and retained in slags, although the retained substance was not identified. Neither fairly high temperatures nor a range of chemicals, including water, were effective in breaking down the hard, glassy slag to release the sulphur. This suggests that slag disposal will not cause environmental problems and the material might be useful for construction.

COAL CONVERSION WASTEWATER TREATMENT

UNIVERSITY OF ALBERTA, (S.E. HRUDEY), EDMONTON

The researcher is characterizing coal conversion wastewaters for their non-phenolic organic constituents. These substances may inhibit anaerobic biodegradation of phenolic substrates. Existing data on solvent preference for various compound classes, together with the pH-dependence of phenolic extraction, are being used to minimize removal of phenols while maximizing extraction of inhibiting substances in a pretreatment solvent extraction step.

The work has demonstrated the possibility of solvent extraction at optimal pH to allow treatment of essentially full-strength wastewater from coal conversion processes. Process development has proceeded from the batch culture mode to semicontinuous treatment of coal liquefaction wastewater.



This year, research work using the low $NO_x SO_x$ (LNS) burner continued to demonstrate its ability to remove nitrogen and sulphur oxides from combustion gases.

While it is clear that coal marketing is the responsibility of individual coal-producing companies, it is also recognized that some market opportunities can be created or improved by technological innovation or development of existing technologies by industry in collaboration with potential customers and the Alberta Office of Coal Research and Technology. The following projects are examples of this collaborative approach.

COAL USE IN ENHANCED OIL RECOVERY

LUSCAR LTD. (EDMONTON) AND OTHER PARTICIPANTS

The Coal Use in Enhanced Oil Recovery Technical Committee proposes to demonstrate a cost-competitive coal combustion technology for raising the steam used in Alberta's in situ heavy oil projects. This year, a project manager knowledgeable in both heavy oil/bitumen production and steam raising technology was contracted to select a boiler manufacturer to design an innovative, pulverized coal-fired unit as part of an existing installation that uses natural gas.

This project has been given additional impetus by the Alberta Energy Resources Conservation Board decision D86-6 of July 16, 1986, which recommends that active research and development be pursued by the Alberta Office of Coal Research and Technology, the Alberta Oil Sands Technology and Research Authority, and the Canada Centre for Mineral and Energy Technology to produce a suitable coal-based technology for in situ bitumen production. The same decision concludes that at some future time, coal will have an economic advantage over natural gas for this purpose. Hence, pilot testing of coal-fired steam generators should be undertaken before the oil industry decides to make major capital investments in developing heavy oil reserves.

By the end of the fiscal year, a number of boiler manufacturers had been invited to submit conceptual proposals to meet the unique operational criteria identified with enhanced oil recovery projects.

ACTIVATED CARBON FROM COAL

UNIVERSITY OF CALGARY, (E.L. TOLLEFSON), CALGARY

This project focuses on the design, construction and operation of two laboratory-scale furnaces to provide variable but controllable environments for the production of activated carbon from three different coals under a range of conditions. Suitable analyses will be made of the activated carbon products.

The principal innovative feature of the study is the development of process details for the preparation of activated carbons from Coal Valley high volatile bituminous "C" and Roselyn subbituminous "C" coals from Alberta, and from Bienfait lignite coal from Saskatchewan. Because these coals are quite different with respect to activation conditions and resulting products, they should indicate how to prepare a range of activated carbon products using the type of reaction system proposed. This is an important factor because the market is not large enough to support the construction of a special plant for each of several types of activated carbon. The project is being funded through the Coal Research Grants Program.

OTHER PROJECTS

Two studies were undertaken this year that examined some of the fundamentals of coal and its uses in support of projects in specific research areas of interest to industry and the Alberta Office of Coal Research and Technology.

DATA GATHERING FOR RESEARCH PLANNING

COAL MINING RESEARCH COMPANY, DEVON

In its efforts to help make Canadian coal more competitive in world markets, through application of new processing methods and mining techniques, the Coal Mining Research Company needs the advice and support of the entire industry. To gauge the needs of industry more accurately, visits were made to mine sites and corporate head offices to obtain the views of senior management and operating personnel. The results of this study have been incorporated in the company's Strategic Plan (1982-92).

A meeting was held June 24, 1986, to familiarize senior executives and managers of coal-producing companies, end users and the Bank of Montreal Global Energy Group with the capabilities of the Coal Research Centre, Devon. A task force comprising representatives from industry and the Coal Research Centre, Devon was created to assess the research and development needs of the industry. The first meeting of this group was held September 9, 1986.

ELECTROLYSIS OF COAL SLURRIES

UNIVERSITY OF CALGARY, (V.I. BIRSS), CALGARY

The electrochemical oxidation of acidified coal slurries of different types of subbituminous coal samples was carried out in the presence of iron to assess this method of producing commercially useful oxidation products and generating hydrogen gas.

Following work at ambient temperatures (reported last year), research was carried out at higher temperatures (90°C).

A detailed investigation of the kinetics and mechanism of coal oxidation in the acidic slurries has been carried out in parallel with the analysis of the surface of fresh and electrolysed coal particles by Fourier Transform Infra-Red and other techniques.

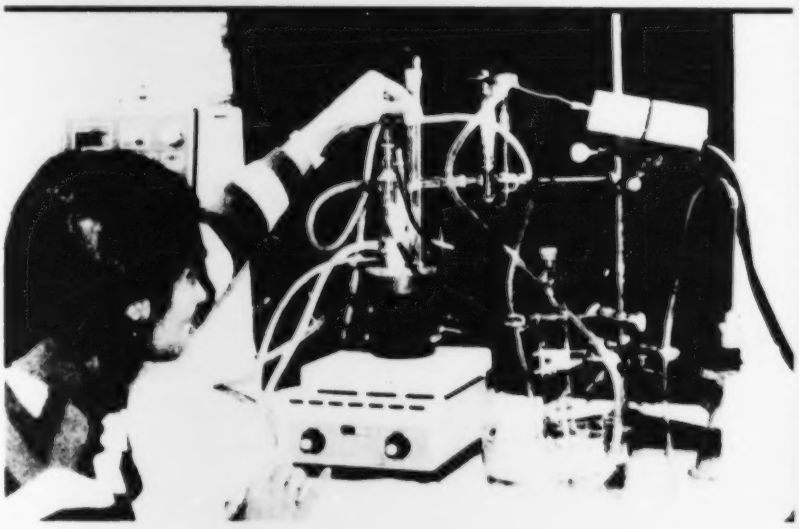
Results showed that the coal was active towards electrochemical oxidation at room temperature, even during long reaction times.

At higher temperatures, the results were particularly promising. The oxidation current remained high for an extended period, even though it dropped slowly with time. Experiments were conducted with varying ratios of coal:iron concentrations to determine the cause of the slow decrease in activity after long electrolysis times. A kinetic analysis indicated that an oxidized organic layer, which gradually formed on the surface of the coal particles, prevented access of Fe^{3+} ions to coal surface sites.

Several novel methods of regenerating oxidized coal surfaces, which bring the coal activity back to its original level, have been developed in this research. These include the in situ alteration of the slurry pH and the production of hydrogen atoms at an electrode in the electrochemical cell.

Alberta coal oxidation has also been carried out in acetic acid-based slurries, in which it is found that considerably less carbon dioxide and a higher concentration of low molecular weight solution-soluble organic products are produced, as compared to the case in sulphuric acid slurries.

The electrochemical oxidation of acidified coal slurries at 90°C is a promising method of producing hydrogen gas and other potentially useful products.



PROJECT EXPENDITURES

During the fiscal year from April 1, 1986 to March 31, 1987, expenditures on approved research projects totalled $9 194 861, of which $5 478 800 was provided by the Alberta Office of Coal Research and Technology. The remainder, $3 716 061, or 40.4 per cent of the total, was contributed by the coal industry.

Funding contributions to approved projects are shown, by year, in Table 1. Contributions to coal-related research since April 1, 1977 are shown in Figure 1. The distribution of funding contributions for the past two years, and projected for 1987/88, is shown in Figure 2.

TABLE 1: FUNDING CONTRIBUTIONS TO APPROVED PROJECTS BY YEAR

	($)											
Project Title	**1977/78**	**1978/79**	**1979/80**	**1980/81**	**1981/82**	**1982/83**	**1983/84**	**1984/85**	**1985/86**	**1986/87**	**Projected Future Funding**	**Total**
Exploration												
Analysis of Coal-Bearing Strata Near Cadomin	–	507	15 762	3 731	–	–	–	–	–	–	–	20 000
Reflective Seismic Investigation of Western Canadian Coalfields	–	–	–	–	35 668	17 760	3 564	–	–	–	–	56 992
Surface Geophysics	–	–	–	–	–	–	–	96 915	112 053	124 500	–	333 468
VLF Geophysical Methods in Coal Exploration	–	–	–	–	–	–	–	4 426	10 420	–	–	14 846
Potential of Geophysical Techniques in Coal Exploration	–	–	–	–	–	–	–	–	69 470	–	–	69 470
Downhole Geophysical Characterization of Overburden	–	–	–	–	–	–	–	–	–	30 667	232 800	263 467
In-seam Coal Characterization	–	–	–	–	–	–	–	–	–	92 718	143 925	236 643
3-D Structural Geometries	–	–	–	–	–	–	–	–	22 873	30 127	–	53 000
Seismic Modelling of Coalfields	–	–	–	–	–	–	–	–	–	24 723	45 927	70 650
Alberta Coal Geology Program	–	–	–	–	–	–	–	–	–	138 110	1 061 890	1 200 000
Sub-Total Exploration	**–**	**507**	**15 762**	**3 731**	**35 668**	**17 760**	**3 564**	**101 341**	**214 816**	**440 845**	**1 484 542**	**2 318 536**
Mining												
Coal Mining Research	14 692	67 595	115 347	181 640	225 662	296 129	358 220	278 838	417 439	–	–	1 955 562
Support Design for Underground Cavities in Weak Rock	132 154	–	–	–	–	–	–	–	–	–	–	132 154
Creep Characteristics of Coal	–	–	–	–	–	–	14 439	2 020	–	–	–	16 459
Coal Mining in 2035	–	–	–	–	–	–	–	–	78 682	–	–	78 682
Geotechnical Properties of Overburden	–	–	–	–	–	–	–	–	71 501	–	–	71 501
Footwall Anchoring	–	–	–	–	–	–	–	–	–	81 246	59 802	141 048
Triaxial Test Development	–	–	–	–	–	–	–	–	–	103 503	–	103 503
Robotics for Mine Control	–	–	–	–	–	–	–	–	–	96 178	–	96 178
Mining 2035 Workshop	–	–	–	–	–	–	–	–	–	25 226	–	25 226
Ground Movement in Coal Mines	–	–	–	–	–	–	–	–	11 469	14 031	–	25 500
Behaviour of Coal Measure Rocks	–	–	–	–	–	–	–	–	–	15 228	24 712	40 000
Deformation and Progressive Failure of Open-Pit Highwalls	–	–	–	–	–	–	–	–	–	44	84 658	84 702
Sub-Total Mining	**146 846**	**67 595**	**115 347**	**181 640**	**225 662**	**296 129**	**372 659**	**280 858**	**579 091**	**335 516**	**169 172**	**2 770 515**
Preparation and Upgrading												
Coal Preparation Research	39 845	183 315	312 815	492 675	612 060	803 189	835 845	1 188 731	224 014	–	–	4 692 489
Coal Ash Monitoring System	–	13 555	24 185	25 130	8 763	–	–	–	–	–	–	71 633
Auto Medium Cyclones	–	–	–	–	22 929	34 842	37 940	–	–	–	–	95 711
Beneficiation of Coal by Agglomeration in Pipelines	–	–	–	49 944	60 947	74 523	22 220	–	–	–	–	207 634
Agglomeration of Low-Rank Alberta Thermal Coals	–	–	–	–	–	136 754	–	–	–	–	–	136 754
Coal Beneficiation Process	–	–	–	–	–	–	–	68 546	153 438	595 072	287 944	1 105 000
Agglomeration for Beneficiation	–	–	–	–	–	–	–	–	18 444	31 328	–	49 772
Numerical Analysis of Process Yield Losses	–	–	–	–	–	–	–	–	56 000	19 795	–	75 795
Properties of Thermally Dried Coal	–	–	–	–	–	–	–	–	99 459	45 000	–	144 459

TABLE 1: FUNDING CONTRIBUTIONS TO APPROVED PROJECTS BY YEAR

($)

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	Projected Future Funding	Total
Washery Optimization	–	–	–	–	–	–	–	–	–	93 876	147 240	241 116
Coal Comminution	–	–	–	–	–	–	–	–	–	54 466	–	54 466
Stabilization of Dried Coals	–	–	–	–	–	–	–	–	–	37 423	–	37 423
Advanced Processes for Low-Rank Coals	–	–	–	–	–	–	–	–	–	79 392	–	79 392
Preparation and Upgrading Assistance to the Alberta Office of Coal Research and Technology	–	–	–	–	–	–	–	–	–	705	41 295	42 000
Sub-Total Preparation and Upgrading	**39 845**	**196 870**	**337 000**	**567 749**	**704 699**	**912 554**	**1 032 759**	**1 257 277**	**551 355**	**957 057**	**476 479**	**7 033 644**
Combustion												
Prediction of Coal Combustibility	–	–	–	–	–	–	–	–	83 359	56 463	113 925	253 747
Combustion of Agglomerated Coal	–	–	–	–	–	–	–	2 061	22 950	8 325	–	33 336
IEA Coal Combustion Science	–	–	–	–	–	–	–	–	101 619	184 708	179 237	465 564
Combustion Program Development	–	–	–	–	–	–	–	–	39 612	18 991	18 000	76 603
Combustion Characteristics of Alberta Coals	–	–	–	–	–	–	–	–	97 849	91 121	–	188 970
Combustion Process Research	–	–	–	–	–	–	–	–	25 215	125 000	–	150 215
Combustibility of Agglomerates	–	–	–	–	–	–	–	–	–	14 156	–	14 156
Causes of Spontaneous Combustion of Western Canadian Coals	–	–	–	–	–	–	–	–	–	52 040	49 464	101 504
Sub-Total Combustion	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**2 061**	**370 604**	**600 832**	**360 626**	**1 284 095**
Liquefaction												
ENR ARC Coal Conversion Research	2 055	–	37 412	1 182 372	3 135 406	4 158 527	3 034 865	2 085 164	706 548	–	–	14 342 349
Coal Liquefaction Study	–	–	–	151 864	–	–	–	–	–	–	–	151 864
Hydroprocessing of Coal-Based Liquids	–	–	–	–	–	45 593	34 463	4 880	–	–	–	84 936
Supercritical Gas Extraction of Coal	–	–	–	–	–	30 611	31 208	5 473	–	–	–	67 292
Coal Liquefaction Feasibility Study	–	–	–	–	–	–	–	90 553	–	–	–	90 553
PYROSOL Process Review	–	–	–	–	–	–	–	–	7 006	–	–	7 006
New Liquefaction Processes	–	–	–	–	–	–	–	–	32 949	198 000	–	230 949
PYROSOL Process Development	–	–	–	–	–	–	–	–	–	2 282 650	1 985 850	4 268 500
Liquefaction Process Improvement	–	–	–	–	–	–	–	–	51 059	–	–	51 059
Liquefaction Process Evaluation	–	–	–	–	–	–	–	–	26 191	51 600	–	77 791
Chemistry of Coal Liquefaction	–	–	–	–	–	–	–	–	84 232	121 000	337 000	542 232
Functional Group Analysis of Coal Liquids	–	–	–	–	–	–	–	–	30 515	49 793	10 692	91 000
Isotopic Analysis of Co-processing Schemes	–	–	–	–	–	–	–	–	22 082	51 918	–	74 000
Supercritical Gas Extraction of Coal	–	–	–	–	–	–	–	–	–	27 588	54 687	82 275
Hydroprocessing of Coal-Derived Liquids	–	–	–	–	–	–	–	–	–	15 607	89 793	105 400
Liquefaction of Coal with Natural Gas	–	–	–	–	–	–	–	–	–	–	35 750	35 750
Isotopic Studies of Coal Bitumen Co-processing	–	–	–	–	–	–	–	–	–	–	122 140	122 140
Sub-Total Liquefaction	**2 055**	**–**	**37 412**	**1 334 236**	**3 135 406**	**4 234 731**	**3 100 536**	**2 186 070**	**960 582**	**2 798 156**	**2 635 912**	**20 425 096**

TABLE 1: FUNDING CONTRIBUTIONS TO APPROVED PROJECTS BY YEAR

($)

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	Projected Future Funding	Total
Gasification												
Gasification of Western Canadian Coals	–	–	–	–	–	–	–	–	–	38 500	–	38 500
Gasification Process Research	–	–	–	–	–	–	–	–	–	12 207	86 000	98 207
Gasification Properties of Alberta Coals	–	–	–	–	–	–	–	–	–	34 957	130 000	164 957
Gasification Behaviour of Alberta Coals	–	–	–	–	–	–	–	–	–	5 466	188 000	193 466
Corrosion in Gasification Systems	–	–	–	–	–	–	–	–	–	50 871	43 529	94 400
Sub-Total Gasification	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**142 001**	**447 529**	**589 530**
Transportation												
Coal Slurry Pipeline Research	–	–	–	–	–	–	114 903	150 333	22 717	–	–	287 953
Sub-Total Transportation	**–**	**–**	**–**	**–**	**–**	**–**	**114 903**	**150 333**	**22 717**	**–**	**–**	**287 953**
Environment												
Coal Conversion Wastewater Treatment	–	–	–	–	–	30 000	57 890	–	–	–	–	87 890
Low NO_x SO_x Burner	–	–	–	–	–	–	–	–	–	50 028	–	50 028
Coal Conversion Wastewater Treatment	–	–	–	–	–	–	–	–	17 305	38 577	8 118	64 000
Sub-Total Environment	**–**	**–**	**–**	**–**	**–**	**30 000**	**57 890**	**–**	**17 305**	**88 605**	**8 118**	**201 918**
Markets												
Production of Activated Carbon	–	–	–	32 364	7 077	–	–	759	–	–	–	40 200
Fuel Options for Enhanced Oil Recovery	–	–	–	–	–	–	–	–	15 000	–	–	15 000
Conversion from Oil to Coal Water Fuel	–	–	–	–	–	–	–	–	26 093	9 283	–	35 376
Coal Use in Enhanced Oil Recovery	–	–	–	–	–	–	–	–	–	17 995	17 000	34 995
Activated Carbon from Coal	–	–	–	–	–	–	–	–	–	31 738	68 262	100 000
Sub-Total Markets	**–**	**–**	**–**	**32 364**	**7 077**	**–**	**–**	**759**	**41 093**	**59 016**	**85 262**	**225 571**
Other												
Coal Technology Information Centre	–	–	–	–	–	143 753	114 830	123 537	189 000	–	–	571 120
CTIC Review	–	–	–	–	–	–	–	16 997	–	–	–	16 997
Data Gathering for Research Planning	–	–	–	–	–	–	–	–	10 784	39 904	–	50 688
Electrolysis of Coal Slurries	–	–	–	–	–	–	–	–	26 655	65 588	20 757	113 000
Analysis of Distributed Chemical and Physical Properties of Coal	–	–	–	–	–	–	–	–	–	–	54 200	54 200
Sulphur Isotope Studies of Coal	–	–	–	–	–	–	–	–	–	–	63 200	63 200
Magnetic and Electrical Properties of Alberta Coals	–	–	–	–	–	–	–	–	–	–	109 450	109 450
Sub-Total Other	**–**	**–**	**–**	**–**	**–**	**143 753**	**114 830**	**123 537**	**243 436**	**106 800**	**247 607**	**979 963**
TOTAL	**188 746**	**264 972**	**505 521**	**2 119 720**	**4 108 512**	**5 634 927**	**4 797 141**	**4 102 236**	**3 000 999**	**5 478 800**	**5 915 247**	**36 116 821**

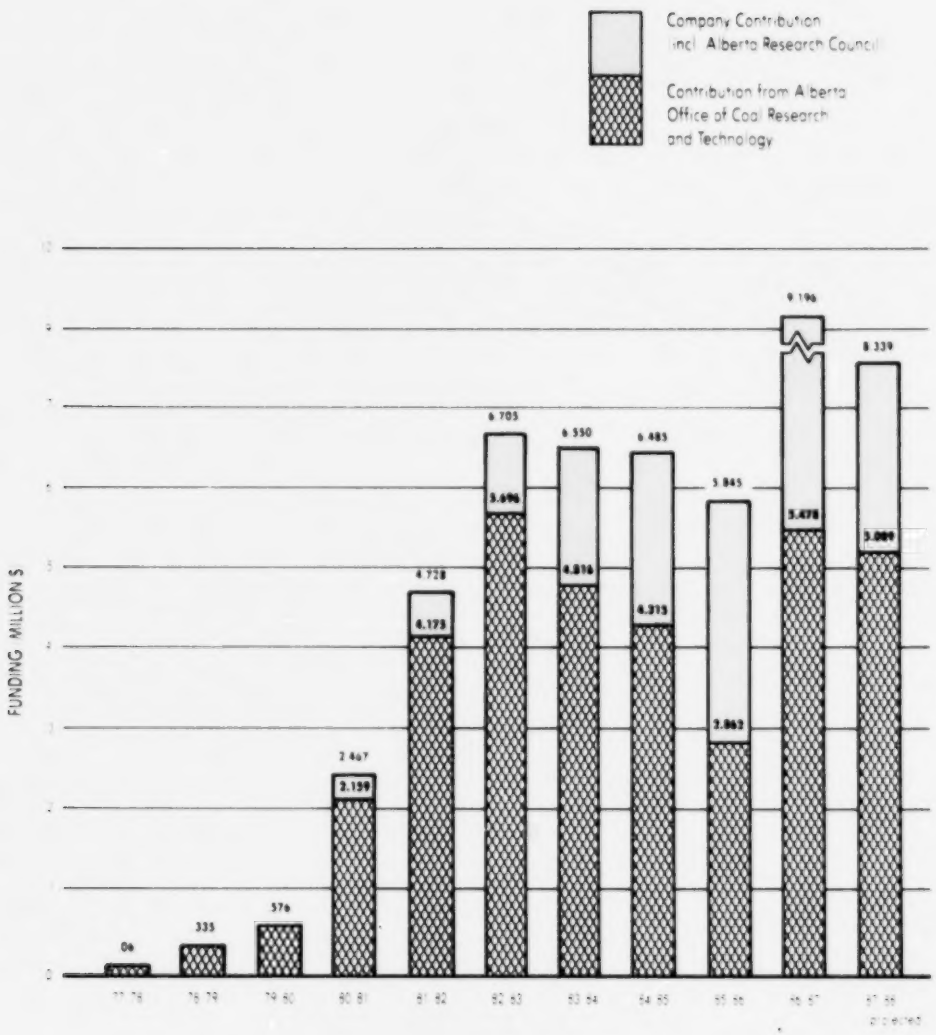


FIGURE 1: Research Expenditure on Approved Projects, (excluding Coal Research Centre, Devon).

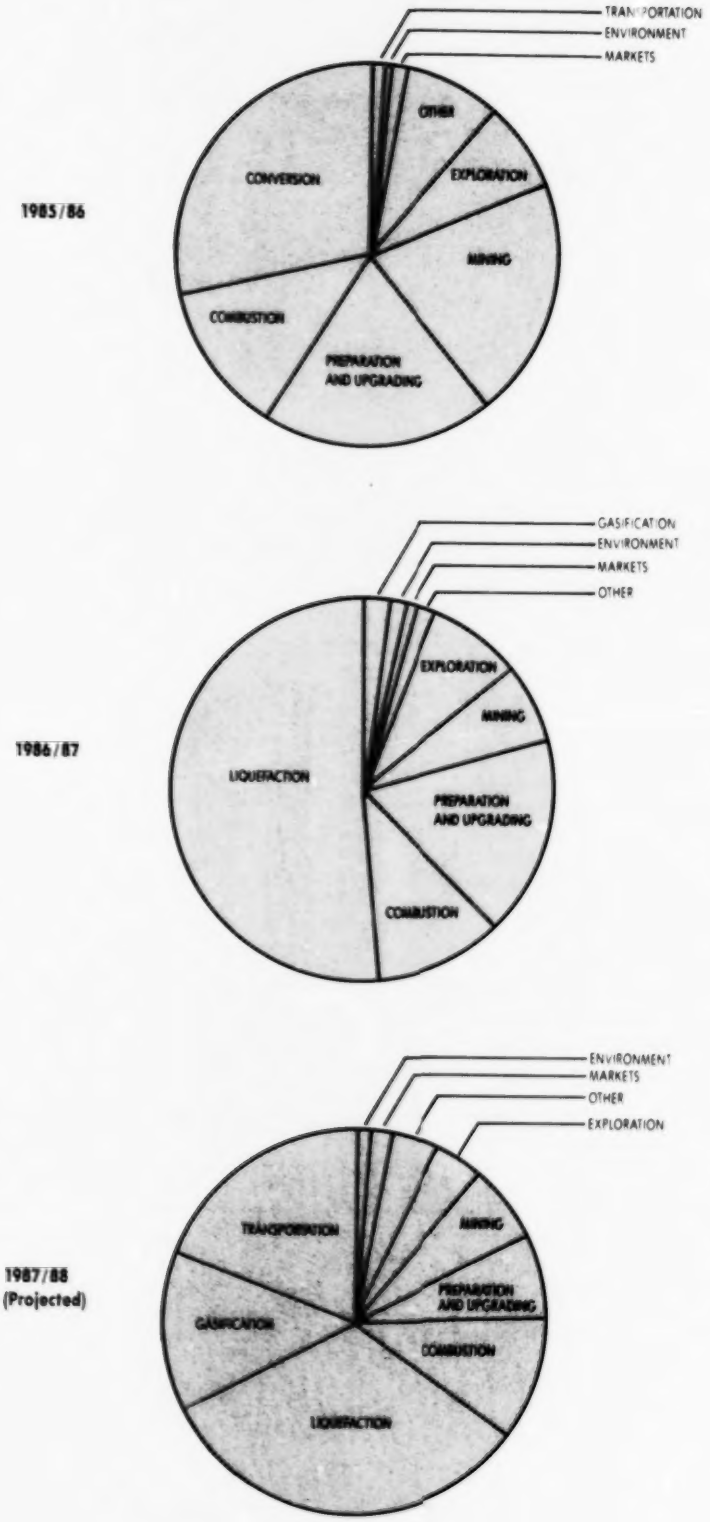


FIGURE 2: Distribution of Alberta Office of Coal Research and Technology Funding Contributions.

REPORTS & PUBLICATIONS

REPORTS, PUBLICATIONS, AND CONFERENCE PRESENTATIONS RESULTING FROM PROJECTS COMPLETED IN 1985/86

COAL MINING RESEARCH COMPANY

CMRC Staff. 1986. **Coal Mining in Alberta, 1986-2035. Volumes I-III.** CMRC Report 8519-T.

Thornton, S.E. and M.J. Kramer. 1986. **CMRC Geotechnical Laboratories.** CMRC Report 8513-T.

White, P.M.T. and S.G. Butcher. 1986. **A/CERRF Project #9 — Coal Mining Research Company — 1977/1985. Final Report.**

Wilson, R.A. and G.E. Davies. 1986. **Present and Potential Applications of Geophysics to Coal Exploration in Alberta.** CMRC Report 8545-T.

ALBERTA RESEARCH COUNCIL

Aitchison, D.A., P. Clark, B. Ignasiuk and L.K. Lee. 1986. **Reaction Severity and Feedstock Pretreatment in Co-processing.** U.S. DOE Direct Liquefaction Contractors Review Meeting, Pittsburgh, October 21-22.

Kovacik, G., M. Oguztoreli and B. Ozum. 1987. **Co-processing of Alberta Subbituminous Coal and Bitumen in a Semi-Continuous Hot Charge-Discharge Unit.** Can. J. Chem. Eng. 65:286-292.

Lee, L.K. and D.A. Aitchison. 1986. **Process Improvements: A Review of Co-processing Technology.**

Lee, L.K., P.D. Clark, E. Fitzpatrick and R. Hawkins. 1986. **The Liquefaction of Highvale Coal in Anthracene Oil Using Dispersed Molybdenum and Alumina Supported Metal Catalysts.** 10th Canadian Symposium on Catalysis, Kingston, Ontario.

Selucky, M.L. 1986. **Coal Liquid Characterization Technical Report.**

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TransAlta Utilities Corporation ..... p. 5
..... p. 23
D.A. Spratt ..... p. 6
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..... p. 15 upper right
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